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REPORT

OF THE

SIXTY-FOURTH MEETING

OF THE

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BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

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ERRATA.

In 1893 (*Nottingham*) *Report.*

Page 571, line 31. Omit 'Dr. J. N. Keynes.'

In 1894 (*Oxford*) *Report.*

Page 651, line 18. For West *read* North.
Page 681. For Professor A. *W.* W. Hubrecht *read* Professor A. *A.* W. Hubrecht.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

THE ASSOCIATION contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

LIFE MEMBERS shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.
   New Life Members who have paid Ten Pounds as a composition.
   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.
   Annual Members who have intermitted their Annual Subscription.
   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s.* 6*d.* per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

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[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[1]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

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[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the Sectional Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee, except for Thursday and Saturday.[5]

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

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necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879.

[2] Swansea, 1880.

[3] Edinburgh, 1871.

[4] The meeting on Saturday is optional, Southport, 1883.

[5] Nottingham, 1893.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

10 On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxxi), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may
ffered by their Members for the advancement of Science. They are
ally requested to review the recommendations adopted at preceding
ings, as published in the volumes of the Association, and the com-
made to the Sections at this Meeting, for the purposes of
finite points of research to which individual or combined
be usefully directed, and branches of knowledge on the
gress of which Reports are wanted; to name individuals or
r the execution of such Reports or researches; and to state
o what degree, these objects may be usefully advanced by
tion of the funds of the Association, by application to
hilosophical Institutions, or Local Authorities.

appointment of Committees for special objects of Science,
that *all Members of the Committee should be named, and*

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were adopted by the General Committee, Plymouth, 1877.

e following sentence were added by the General Committee, Edin-

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[2]

Notices regarding Grants of Money.

Committees and individuals to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Chairman of a Committee to whom a money grant has been made must forward to the General Officers, before July 1, a statement of the sums which have been expended, with vouchers, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire on June 30 following; nor is the Treasurer authorised, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General

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[1] Revised by the General Committee, Bath, 1888.

[2] Passed by the General Committee at Sheffield, 1879.

Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Rücker, F.R.S., Burlington House, London, W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public, commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

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[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee, except for Thursday and Saturday.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[3]

Corresponding Societies.[4]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Assistant General Secretary of the Association, a schedule, properly filled up, which will be issued by him, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association

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[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee at Leeds, 1890.
[4] Passed by the General Committee, 1884.

a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of[1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year —observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

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[1] Passed by the General Committee at Belfast, 1874.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The **EARL FITZWILLIAM**, D.C.L., F.R.S., F.G.S., &c. York, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The **REV. W. BUCKLAND**, D.D., F.R.S., F.G.S., &c. Oxford, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell M.A., F.R.S., &c.
The **REV. ADAM SEDGWICK**, M.A., V.P.R.S., V.P.G.S. Cambridge, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. Edinburgh, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The **REV. PROVOST LLOYD**, LL.D. Dublin, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The **MARQUIS OF LANSDOWNE**, D.C.L., F.R.S. Bristol, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The **EARL OF BURLINGTON**, F.R.S., F.G.S., Chancellor of the University of London Liverpool, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution Liverpool.
The **DUKE OF NORTHUMBERLAND**, F.R.S., F.G.S., &c. Newcastle-on-Tyne, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The **REV. W. VERNON HARCOURT**, M.A., F.R.S., &c. Birmingham, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The **MARQUIS OF BREADALBANE**, F.R.S. Glasgow, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The **REV. PROFESSOR WHEWELL**, F.R.S., &c. Plymouth, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The **LORD FRANCIS EGERTON**, F.G.S. Manchester, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The **EARL OF ROSSE**, F.R.S. Cork, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The **REV. G. PEACOCK**, D.D. (Dean of Ely), F.R.S. York, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.

WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S Sir Philip de Malpas Grey Egerton, Bart., M.P The Right Hon. W. E. Gladstone, D.C.L., M.P S. R. Graves, Esq., M.P Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S James P. Joule, Esq., LL.D., D.C.L., F.R.S Joseph Mayer, Esq., F.S.A., F.R.G.S	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.

PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau. Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B. M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.

SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord-Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord-Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon. M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., F.R.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S. The Right Hon. W. L. Jackson, M.P. The Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord-Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S. Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord-Lieut. of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland. His Grace the Duke of Newcastle The Right Hon. Lord Belper. The Mayor of Nottingham The Right Hon. Sir W. R. Grove, M.A., D.C.L., LL.D., F.R.S., F.R.S.E. Sir John Turney, J.P. Professor Michael Foster, M.A., Sec.R.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.
The MOST HON. THE MARQUIS OF SALISBURY, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford. OXFORD, August 8, 1894.	The Right Hon. the Earl of Jersey, G.C.M.G., Lord-Lieutenant of the County of Oxford The Right Hon. Lord Wantage, K.C.B., V.C., Lord-Lieutenant of Berkshire The Right Hon. the Earl of Rosebery, K.G., D.C.L., F.R.S. The Right Rev. the Lord Bishop of Oxford, D.D. The Right Hon. Lord Rothschild, Lord-Lieutenant of Buckinghamshire. The Right Hon. Lord Kelvin, D.C.L., Pres.R.S. The Rev. the Vice-Chancellor of the University of Oxford. The Mayor of Oxford. Sir W. R. Anson, D.C.L., Warden of All Souls College. Sir Bernhard Samuelson, Bart., M.P., F.R.S. Sir Henry Dyke Acland, Bart., M.D., F.R.S., Regius Professor of Medicine. The Rev. the Master of Pembroke College, Sedleian Professor of Natural Philosophy. Dr. J. J. Sylvester, F.R.S., Savilian Professor of Geometry.	Gilbert C. Bourne, Esq., M.A. G. C. Druce, Esq., M.A. D. H. Nagel, Esq., M.A.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries
MATHEMATICAL AND PHYSICAL SCIENCES.		
COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.		
1832. Oxford	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
SECTION A.—MATHEMATICS AND PHYSICS.		
1835. Dublin	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S.	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton.	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.

Date and Place	Presidents	Secretaries
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S., F.R.S.E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin.......	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford......	Rev. B. Price, M.A., F.R.S....	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath.........	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee ...	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S.	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter......	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh	Prof. P. G. Tait, F.R.S.E. ...	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ...	W. De La Rue, D.C.L., F.R.S.	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S. .	Prof. W. K. Clifford, Prof. Forbes, J. W. L. Glaisher, Prof. A. S. Herschel.
1874. Belfast......	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof. Balfour Stewart, M.A., LL.D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.
1876. Glasgow ...	Prof. Sir W. Thomson, M.A., D.C.L., F.R.S.	Prof. W. F. Barrett, J. T. Bottomley, Prof. G. Forbes, J. W. L. Glaisher, T. Muir.
1877. Plymouth...	Prof. G. C. Foster, B.A., F.R.S., Pres. Physical Soc.	Prof. W. F. Barrett, J. T. Bottomley, J. W. L. Glaisher, F. G. Landon.
1878. Dublin......	Rev. Prof. Salmon, D.D., D.C.L., F.R.S.	Prof. J. Casey, G. F. Fitzgerald, J. W. L. Glaisher, Dr. O. J. Lodge.
1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.

Date and Place	Presidents	Secretaries
1880. Swansea ...	Prof. W. Grylls Adams, M.A., F.R.S.	W. E. Ayrton, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.
1881. York.........	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	Prof. W. E. Ayrton, Dr. O. J. Lodge, D. MacAlister, Rev. W. Routh.
1882. Southampton.	Rt. Hon. Prof. Lord Rayleigh, M.A., F.R.S.	W. M. Hicks, Dr. O. J. Lodge, D. MacAlister, Rev. G. Richardson.
1883. Southport	Prof. O. Henrici, Ph.D., F.R.S.	W. M. Hicks, Prof. O. J. Lodge, D. MacAlister, Prof. R. C. Rowe.
1884. Montreal ...	Prof. Sir W. Thomson, M.A., LL.D., D.C.L., F.R.S.	C. Carpmael, W. M. Hicks, Prof. A. Johnson, Prof. O. J. Lodge, Dr. D. MacAlister.
1885. Aberdeen...	Prof. G. Chrystal, M.A., F.R.S.E.	R. E. Baynes, R. T. Glazebrook, Prof. W. M. Hicks, Prof. W. Ingram.
1886. Birmingham	Prof. G. H. Darwin, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. J. H. Poynting, W. N. Shaw.
1887. Manchester	Prof. Sir R. S. Ball, M.A., LL.D., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. H. Lamb, W. N. Shaw.
1888. Bath..........	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff......	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1894. Oxford......	Prof. A. W. Rücker, M.A., F.R.S.	Prof. W. H. Heaton, Prof. A. Lodge, J. Walker.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol......	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.

Date and Place	Presidents	Secretaries
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin......	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, Dr. W. R. Eaton Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S., F.C.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, H. Forster Morley, R. E. Moyle, W W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S.	H. Forster Morley, D. H. Nagel, W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S., F.C.S.	C. H. Bothamley, Dr. H. Forster Morley, Dr. W. W. J. Nicol, Dr. G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S., F.C.S.	Dr. J. Gibson, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, Dr. W. W. J. Nicol.
1894. Oxford......	Prof. H. B. Dixon, M.A., F.R.S.	A. Colefax, W. W. Fisher, Arthur Harden, H. Forster Morley.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place	Presidents	Secretaries
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin......	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

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[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page lx.

Date and Place	Presidents	Secretaries
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow	Prof. John Young, M.D.	J. Armstrong, F. W. Rudler, W. Topley.
1877. Plymouth	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield	Prof. P. M. Duncan, F.R.S.	W. Topley, G. Blake Walker.
1880. Swansea	H. C. Sorby, F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.
1894. Oxford	L. Fletcher, M.A., F.R.S.	F. A. Bather, A. Harker, Clement Reid, W. W. Watts.

Date and Place	Presidents	Secretaries
BIOLOGICAL SCIENCES.		
COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.		
1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh .	Prof. Graham.....................	W. Yarrell, Prof. Burnett.
SECTION D.—ZOOLOGY AND BOTANY.		
1835. Dublin......	Dr. Allman.........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D.......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.
SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.		
[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lix.]		
1848. Swansea ...	L. W. Dillwyn, F.R.S..........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

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[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lix.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D., F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

Date and Place	Presidents	Secretaries
1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh .	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

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[1] At a meeting of the General Committee in 1865, it was resolved 'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W.R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S.—*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.[1]	Prof. A. Gamgee, M.D., F.R.S.—*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[2]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal ...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.
1885. Aberdeen ...	Prof. W. C. McIntosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.

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[1] The Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] Anthropology was made a separate Section, see p. lxvi.

Date and Place	Presidents	Secretaries
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Prof. F. W. Oliver, H. Wager, Prof. H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, Prof. W. Stirling, H. Wager.
1893. Nottingham[1]	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, Prof. J. B. Farmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Dr. W. B. Ransom, W. L. Sclater.
1894. Oxford	Prof. I. Bayley Balfour, M.A., F.R.S.	W. W. Benham, Prof. J. B. Farmer, Prof. W A. Herdman, Prof. S. J. Hickson, G. Murray, W. L. Sclater.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. J. Haviland	Dr. H. J. H. Bond, Mr. G. E. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. J. C. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. P. M. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

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[1] Physiology was made a separate Section, see p. lxvi.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S.	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1]	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. liii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. J. C. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea		G. Grant Francis.
1849. Birmingham		Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

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[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lvi.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page lvii.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S..........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S..........	J.W.Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place	Presidents	Secretaries
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H.W.Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S..........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.

Date and Place	Presidents	Secretaries
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.
1894. Oxford......	Capt. W. J. L. Wharton, R.N., F.R.S.	John Coles, W. S. Dalgleish, H. N. Dickson, Dr. H. R. Mill.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol.......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S........	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

Date and Place	Presidents	Secretaries
1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford......	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.,..	David Chadwick, Prof. R. C. Christie, E. Macrory, Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S....	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath.........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne. F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers............	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich....	Samuel Brown	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter......	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P....	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol......	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin......	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.

Date and Place	Presidents	Secretaries
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D., V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, Prof. J. E. C. Munro, G. H. Sargant.
1888. Bath	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, Prof. H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.
1894. Oxford	Prof. C. F. Bastable, M.A., F.S.S.	E. Cannan, Prof. E. C. K. Gonner, W. A. S. Hewins, H. Higgs.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.

Date and Place	Presidents	Secretaries
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull.........	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath.........	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.

Date and Place	Presidents	Secretaries
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P.Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath.........	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S., F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff.......	T. Forster Brown, M.Inst.C.E.,	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.
1894. Oxford......	Prof. A. B. W. Kennedy, F.R.S., M.Inst.C.E.	Prof. T. Hudson Beare, C. W. Cooke, W. B. Marshall, Rev. F. J. Smith.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath.........	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas. R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff......	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.
1894. Oxford......	Sir W. H. Flower, K.C.B., F.R.S.	H. Balfour, Dr. J. G. Garson, H. Ling Roth.

PHYSIOLOGICAL SCIENCE

SECTION I.—PHYSIOLOGY.

1894. Oxford......	Prof. E. A. Schäfer, F.R.S., M.R.C.S.	Prof F. Gotch, Dr. J. Haldane, M. S, Pembrey.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy,F.R.S.,Astron.Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive Substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S.	The Dodo (*Didus ineptus*).
1848. Swansea	John Percy, M.D., F.R.S.	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S.	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy,F.R.S.,Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform Research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.

Date and Place	Lecturer	Subject of Discourse
1857 Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862 Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S............	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S.......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S.......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S............	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S..........	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S. ..	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S......	Some Recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.

Date and Place	Lecturer	Subject of Discourse
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.	The New Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S....	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvanic and Animal Electricity.
1884. Montreal...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S....	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D....	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton, K.C.M.G.	Explorations in Central Africa.
1888. Bath.........	Prof. W. E. Ayrton, F.R.S....	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff......	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. Milnes Marshall, D.Sc., F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S., F.R.S.E.	Magnetic Induction.
1893. Nottingham	Prof. A. Smithells, B.Sc.	Flame.
	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.
1894. Oxford......	J. W. Gregory, D.Sc., F.G.S.	Experiences and Prospects of African Exploration.
	Prof. J. Shield Nicholson, M.A.	Historical Progress and Ideal Socialism.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental Illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Prof. Odling, F.R.S.............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snowflakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S.........	Comets.
1885. Aberdeen ...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath	Sir John Lubbock, Bart., M.P., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes	Spontaneous Combustion.
1894. Oxford	Prof. W. J. Sollas, F.R.S. ...	Geologies and Deluges.

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				£	s.	d.
Balance brought forward				391	1	9
Life Compositions				280	0	0
New Annual Members' Subscriptions				134	0	0
Annual Subscriptions				558	0	0
Sale of Associates' Tickets				762	0	0
Sale of Ladies' Tickets				268	0	0
Sale of Index, 1861–90	£85	1	3			
Sale of other Publications	145	5	4			
				230	6	7
Interest on Exchequer Bills				12	14	11
Dividends on Consols				226	18	8
Dividends on India 3 per Cents.				104	17	0
Unexpended Balance of Grant for investigating the Physiological Action of Oxygen in Asphyxia				1	0	11
Unexpended balance of Grant to Wave-lengths Committee				136	4	0
Income Tax returned				25	11	8
Sale of Consols—£962 16 7 at $100\frac{1}{8}$ =	£971	5	1			
Less Stamp and Commission	1	5	1			
				970	0	0
Exchequer Bills transferred from Investments Account				500	0	0
				£4600	15	6

Investments

	£	s.	d.
June 30, 1893: Consols	8500	0	0
India 3 per Cents	3600	0	0
In hands of General Treasurer:			
Exchequer Bills	500	0	0
	£12,600	0	0

from July 1, 1893, to June 30, 1894. *Cr.*

1893-94. PAYMENTS.

	£	s.	d.	£	s.	d.	£	s.	d.
Expenses of Nottingham Meeting, including Printing, Advertising, Payment of Clerks, &c.							133	16	8
Rent and Office Expenses							52	12	6
Salaries							503	15	0
Printing, Binding, &c.:—1892-93				£1019	5	7			
" " 1893-94				942	7	9			
" " Index, 1861-90				221	0	0			
							2182	13	4
Payment of Grants made at Nottingham:—									
Electrical Standards				25	0	0			
Photographs of Meteorological Phenomena				10	0	0			
Tables of Mathematical Functions				15	0	0			
Recording the Direct Intensity of Solar Radiation				5	5	6			
Wave-length Tables of the Spectra of the Elements				10	0	0			
Action of Light upon Dyed Colours				5	0	0			
Erratic Blocks				15	0	0			
Fossil Phyllopoda				5	0	0			
Shell-bearing Deposits at Clava, Chapelhall, &c.				20	0	0			
Eurypterids of the Pentland Hills				5	0	0			
New Sections of Stonesfield Slate				14	0	0			
Observations on Earth-tremors				50	0	0			
Exploration of Calf-Hole Cave				5	0	0			
Table at the Naples Zoological Station				100	0	0			
Table at the Plymouth Biological Laboratory				5	0	0			
Zoology of the Sandwich Islands				100	0	0			
Zoology of the Irish Sea				40	0	0			
Structure and Function of the Mammalian Heart				10	0	0			
Observations in South Georgia				50	0	0			
Exploration in Arabia				30	0	0			
Methods of Economic Training				9	10	0			
Anthropometric Laboratory Statistics				5	0	0			
Ethnographical Survey of the United Kingdom				10	0	0			
The Lake Village at Glastonbury				40	0	0			
Anthropometrical Measurements in Schools				5	0	0			
Mental and Physical Condition of Children				20	0	0			
Corresponding Societies				25	0	0			
							633	15	6
In hands of General Treasurer:—									
At Bank of England, Western Branch	£682	9	8						
Less Cheques not presented	89	6	9						
				593	2	11			
Exchequer Bills				500	0	0			
Cash				0	19	7			
							1094	2	6
							£4600	15	6

Account.

	£	s.	d.	£	s.	d.
Consols sold				962	16	7
Exchequer Bills transferred to General Account				500	0	0
Investments June 30, 1894:—Consols	£7537	3	5			
India 3 per Cents	3600	0	0			
				11137	3	5
				£12,600	0	0

Arthur W. Rücker, *General Treasurer.*

Wm. Cunningham, } *Auditors.*
T. E. Thorpe, }

July 13, 1894.

Table showing the Attendance and Receipts

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.......	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.......	235	9
1851, July 2 ..	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds.................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.......	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.......	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20
1885, Sept. 9 ...	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1 ...	Birmingham.........	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31 ...	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5 ...	Bath	Sir F. J. Bramwell, F.R.S......	266	36
1889, Sept. 11 ...	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3 ...	Leeds.................	Sir F. A. Abel, C.B., F.R.S. ...	259	21
1891, Aug. 19 ...	Cardiff	Dr. W. Huggins, F.R.S.........	189	24
1892, Aug. 3 ...	Edinburgh	Sir A. Geikie, LL.D., F.R.S. ...	280	14
1893, Sept. 13 ...	Nottingham	Prof. J. S. Burdon Sanderson...	201	17
1894, Aug. 8 ...	Oxford	The Marquis of Salisbury, F.R.S.	327	21

* Ladies were not admitted by purchased tickets until 1843.

† Tickets of Adm

t Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26&60 H.§	1777	1538 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894

Including Ladies.

§ Fellows of the American Association were admitted as Hon. Members for this Meeting.

REPORT OF THE COUNCIL.

Report of the Council for the Year 1893–94, *presented to the General Committee at Oxford on Wednesday, August* 8, 1894.

The Council have received reports from the General Treasurer during the past year, and his account from July 1, 1893 to June 30, 1894, which has been audited, will be presented to the General Committee.

As the amount of money voted for grants has been subject to considerable fluctuations, and as the expenditure on printing is apt to increase unless carefully watched, the Council appointed a Committee to report on the desirability of equalising the grants made for scientific purposes in different years, and of making, if possible, still further reductions in the expenditure on printing.

The Council received and adopted the following Report from their Committee.

(1) That it is not desirable that the Invested Funds of the Association be increased, and that the floating balance in the hands of the Treasurer might be diminished if the bill for printing, which is now due, were paid out of Capital. The Committee therefore recommend that a sufficient sum be taken out of Capital to allow this to be done.

(2) That the Treasurer be requested to continue the practice, which he began at Nottingham, of presenting to the Committee of Recommendations, at their second meeting, an estimate of the receipts and expenses of the Association for the current financial year.

(3) That it is not advisable to lay down any definite rules as to the amount to be expended in grants, but that as far as circumstances permit the following regulations should be adhered to:—

(α) That 1,000*l.* be at present regarded as the normal annual grant in aid of research.

(β) That this sum be annually granted, unless the estimated floating balance in the hands of the Treasurer at the end of the current financial year is less than 500*l.* or greater than 1,000*l.*

(γ) If the estimated balance falls short of 500*l*, it is desirable that the grant should be reduced. If it exceeds 1,000*l.*, the excess may be regarded as available for increasing the grant above 1,000*l.*

(δ) In the case of a sudden increase of the floating balance above 1,000*l.*, due to an exceptionally large meeting, it is not desirable that the whole of the surplus should be spent at one meeting.

(4) That in view of the large annual expenditure on printing, the Committee recommend that the attention of Committees to whom grants of money are made be drawn to the importance of economy. Good service would be rendered to the Association if members of Committees would remember that they are severally responsible for the reports, and would do their best to make them as short and inexpensive as is consistent with their utility.

In accordance with the recommendation that the printer's bill then due should be paid out of Capital, the Council authorised the Trustees to sell an amount of stock sufficient for this purpose.

An invitation to hold the Annual Meeting of the Association at Liverpool in 1896 has been received, and will be brought before the General Committee on Monday; communications in reference to the Meeting of the Association in 1897 have been received from Toronto.

The Council recommend that the Mayor of Oxford, Sir W. R. Anson, Warden of All Souls' College, and Professor Sylvester be elected Vice-Presidents of the Association.

The Council having been informed that Mr. L. A. Selby-Bigge, one of the Local Secretaries, was obliged to resign his office, owing to his having accepted the appointment of Assistant Charity Commissioner, Mr. D. H. Nagel was nominated Secretary in his place.

The Council have elected the following Foreign Men of Science Corresponding Members:—

Prof. Christian Bohr, Copenhagen.
Prof. W. C. Brögger, Christiania.
Prof. W. Einthoven, Leiden.
Prof. Heger, Brussels.
Dr. R. Hertwig, Munich.
Dr. Hildebrand, Stockholm.
M. Henri Moissan, Paris.

Resolutions referred to the Council for consideration and action if desirable:—

(1) That the recommendations regarding the times at which the Sections and Sectional Committees shall meet, which have been received from the Sectional Committees, be referred to the Council.

The Council, having regard to the fact that the enforcement of the same hour of meeting for all Sections would be contrary to the expressed wish of some of the Sections, resolved that the times of meeting of the Sections and Committees be arranged by the several Organising Committees, and be communicated to the General Officers at least one month before the Annual Meeting; and that the times so fixed be regularly adhered to throughout the Meeting on every day except Thursday and Saturday, in respect of which days the hours may be settled, as at present, by the Sectional Committees. If no such resolution be received from an Organising Committee, the times of meeting will be arranged as follows:—Section at 11 A.M., Committee at 10 A.M.

(2) That the resolution received from the Committees of Sections C and G, proposing a change in the rule relating to the appointment of Committees for special objects of science, be referred to the Council.

The Council, having considered the question, do not recommend any change in this rule.

In consequence of the establishment of a separate Section of Physiology, Animal and Vegetable, it seemed likely that papers on botanical subjects might be divided between this Section and that of Biology. The Council received a communication from a meeting of Botanists, held last November, pointing out the inconvenience that was likely to arise from such a division; and they were asked to appoint a Committee to confer with a Committee of Botanists, who would represent the views of the meeting. The Council, after receiving their Committee's Report, resolved to recommend to the General Committee that, instead of Section D and Section I as at present constituted, there be three Sections, namely Section D, Zoology; Section I, Physiology; and Section K, Botany

The Council also propose that the word 'Mineralogy' be omitted from the title of Section B, as papers on Mineralogy are read not only in this Section but also in the Physical Section and in the Geological Section.

By a rule of the Association, proposals for a change in the titles of Sections must be referred to the Committee of Recommendations for a report. This Committee will be able to consider any representations which may be made to them by the Committees of the Sections which would be affected by the proposed changes.

The Report of the Corresponding Societies Committee for the past year has been received and will be presented to the General Committee.

It is proposed in future to print the account of the Conference of Delegates in the Annual Report of the same year instead of in that of the following year. The Report of the Oxford Meeting will therefore contain an account of the proceedings of the Conference both at Nottingham and at Oxford.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola, Sir Douglas Galton, Sir Rawson Rawson, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Mr. W. Topley, Professor T. G. Bonney, Mr. T. V. Holmes, Professor E. B. Poulton, Mr. Cuthbert Peek, and the Rev. Canon Tristram, is hereby nominated for reappointment by the General Committee.

The Council nominate Professor Meldola, F.R.S., Chairman, Mr. Cuthbert E. Peek, Vice-Chairman, and Mr. T. V. Holmes, Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Oxford.

In accordance with the regulations, the retiring Members of the Council will be :—

Sir R. S. Ball.
R. T. Glazebrook, Esq.
Prof. A. H. Green.
Prof. H. Sidgwick.
Dr. H. Woodward.

The Council recommend the re-election of the other Ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list :—

Anderson, Dr. W., F.R.S.
Ayrton, Prof. W. E., F.R.S.
Baker, Sir B., K.C.M.G., F.R.S.
Boys, Prof. C. Vernon, F.R.S.
Edgeworth, Prof. F. Y., M.A.
Evans, Sir J., K.C.B., F.R.S.
*Foxwell, Prof. H. S., M.A.
*Herdman, Prof. W. A., F.R.S.
Horsley, Prof. Victor, F.R.S.
*Lankester, Prof. E. Ray, F.R.S.
Liveing, Prof. G. D., F.R.S.
Lodge, Prof. Oliver J., F.R.S.
Markham, Clements R., Esq., C.B., F.R.S.
Meldola, Prof. R., F.R.S.
Preece, W. H., Esq., C.B., F.R.S.
Ramsay, Prof. W., F.R.S.
Reinold, Prof. A. W., F.R.S.
Reynolds, Prof. J. Emerson, M.D., F.R.S.
Symons, G. J., Esq., F.R.S.
*Teall, J. J. H., Esq., F.R.S.
Thomson, Prof. J. J., F.R.S.
Unwin, Prof. W. C., F.R.S.
*Vines, Prof. S. H., F.R.S.
Ward, Prof. Marshall, F.R.S.
Whitaker, W., Esq., F.R.S.

COMMITTEES APPOINTED BY THE GENERAL COMMITTEE AT THE OXFORD MEETING IN AUGUST 1894.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Professor G. Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and Oliver J. Lodge, Lord Rayleigh, Dr. John Hopkinson, Dr. A. Muirhead, Messrs. W. H. Preece and Herbert Taylor, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald, G. Chrystal, and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, Mr. G. Forbes, and Mr. J. Rennie.	25 0 0
The Application of Photography to the Elucidation of Meteorological Phenomena.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola and Mr. John Hopkinson.	10 0 0
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form. **[Unexpended balance in hands of Committee.]**	*Chairman.*—Lord Rayleigh. *Secretary.*—Professor A. Lodge. Lord Kelvin, Professor A. Cayley, Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, and Professor W. M. Hicks.	
Considering the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. C. Davison. Sir F. J. Bramwell, Professor G. H. Darwin, Professor J. A. Ewing, Mr. Isaac Roberts, Mr. T. Gray, Sir J. Evans, Professor J. Prestwich, Professor E. Hull, Professor G. A. Lebour, Professor R. Meldola, Professor J. W. Judd, Mr. M. Walton Brown, Mr. J. Glaisher, Professor C. G. Knott, Professor J. H. Poynting, and Mr. Horace Darwin.	75 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray, Dr. A. Buchan, Professor R. Copeland, and Hon. R. Abercromby.	50 0 0
To assist the Physical Society in bringing out Abstracts of Physical Papers.	*Chairman.*—Dr. E. Atkinson. *Secretary.* — Professor A. W. Rücker.	100 0 0
To co-operate with the Royal Cornwall Polytechnic Society for the purpose of comparing and reducing the Magnetic Observations of Falmouth Observatory.	*Chairman.*—Mr. Howard Fox. *Secretary.*—Professor W. G. Adams. Professor A. W. Rücker.	50 0 0
To confer with the Astronomer Royal and the Superintendents of other Observatories with reference to the Comparison of Magnetic Standards with a view of carrying out such comparison.	*Chairman.* — Professor A. W. Rücker. *Secretary.*—Mr. W. Watson. Professor A. Schuster and Professor H. H. Turner.	25 0 0
To co-operate with Professor Karl Pearson in the Calculation of certain Integrals.	*Chairman.*—Rev. Robert Harley. *Secretary.*—Dr. A. R. Forsyth. Dr. J. W. L. Glaisher, Professor A. Lodge, and Professor Karl Pearson.	15 0 0
To confer with British and Foreign Societies publishing Mathematical and Physical Papers as to the desirability of securing uniformity in the size of the pages of their Transactions and Proceedings.	*Chairman.*—Professor S. P. Thompson. *Secretary.*—Mr. J. Swinburne. Mr. G. H. Bryan, Mr. C. V. Burton, Mr. R. T. Glazebrook, Professor A. W. Rücker, and Dr. G. Johnstone Stoney.	5 0 0
Preparing a new Series of Wavelength Tables of the Spectra of the Elements.	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Mr. J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	10 0 0
The Action of Light upon Dyed Colours.	*Chairman.*—Dr. T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. W. H. Perkin, Prof. W. J. Russell, Captain Abney, Prof. W. Stroud, and Prof. R. Meldola.	5 0 0
The Investigation of the direct Formation of Haloids from pure Materials.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. W. A. Shenstone. Professor W. R. Dunstan and Mr. C. H. Bothamley.	20 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
Isomeric Naphthalene Derivatives.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.	30 0 0
The Electrolytic Methods of Quantitative Analysis.	*Chairman.*—Professor J. Emerson Reynolds. *Secretary.*—Dr. C. A. Kohn. Professor Frankland, Professor F. Clowes, Dr. Hugh Marshall, Mr. A. E. Fletcher, Mr. D. H Nagel, Mr. T. Turner, and Mr. J. B. Coleman.	40 0 0
Recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. P. F. Kendall. Professors W. Boyd Dawkins, T. McK. Hughes, T. G. Bonney, and J. Prestwich, Messrs. C. E. De Rance, R. H. Tiddeman, J. W. Woodall, and Prof. L. C. Miall.	10 0 0
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Prof. T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.	5 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest. [Last year's grant renewed.]	*Chairman.*—Professor J. Geikie. *Secretary.*—Mr. O. W. Jeffs. Prof. T. G. Bonney, Prof. Boyd Dawkins, Professor T. McKenny Hughes, Dr. V. Ball, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, W. W. Watts, R. H. Tiddeman, J. J. H. Teall, and J. G. Goodchild.	10 0 0
To investigate the Character of the High-level Shell-bearing deposits at Clava, Chapelhall, and other localities.	*Chairman.*—Mr. J. Horne. *Secretary.*—Mr. Dugald Bell. Messrs. J. Fraser, P. F. Kendall, T. F. Jamieson, and David Robertson.	10 0 0
The Investigation of the Eurypterid-bearing Deposits of the Pentland Hills.	*Chairman.*—Dr. R. H. Traquair. *Secretary.*—Mr. M. Laurie. Professor T. Rupert Jones.	3 0 0
To open further Sections in the neighbourhood of Stonesfield in order to show the Relationship of the 'Stonesfield Slate' to the underlying and Overlying Strata.	*Chairman.*—Mr. H. B. Woodward. *Secretary.*—Mr. E. A. Walford. Professor A. H. Green, Dr. H. Woodward, and Mr. J. Windoes.	50 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants		
		£	s.	d.
To explore the Calf-Hole Cave, at the Heights, Skyrethorne, near Skipton.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Rev. E. Jones. Professor W. Boyd Dawkins, Professor L. C. Miall, Mr. P. F. Kendall, Mr. A. Birtwhistle, and Mr. J. J. Wilkinson.	10	0	0
To consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.	*Chairman.*—Professor T. G. Bonney. *Secretary.*—Professor W. J. Sollas. Sir Archibald Geikie, Professors A. H. Green, J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin, S. J. Hickson, and A. Stewart, Captain W. J. L. Wharton, Drs. H. Hicks, J. Murray, W. T. Blanford, Le Neve Foster, and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, A. R. Binnie, J. W. Gregory, and J. C. Hawkshaw, and Hon. P. Fawcett.	10	0	0
To investigate the nature and probable age of the High-level Flint-drift in the Face of the Chalk Escarpment near Ightham, which appears to be productive of Flakes and other Forms of Flint, probably wrought by the hand of Man.	*Chairman.*—Sir John Evans. *Secretary.*—Mr. B. Harrison. Professor J. Prestwich and Professor H. G. Seeley.	10	0	0
To examine the ground from which the remains of *Cetiosaurus* in the Oxford Museum were obtained, with a view to determining whether other parts of the same animal remain in the rock.	*Chairman.*—Professor A. H. Green. *Secretary.*—Mr. James Parker. Earl of Ducie, Professor E. Ray Lankester, and Professor H. G. Seeley.	20	0	0
To appoint Mr. M. D. Hill to investigate the Fertilisation of the Eggs of Echinoderms, Molluscs, and Annelids, or, failing this, to appoint some other competent investigator to carry on a definite piece of work at the Zoological Station at Naples.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. Percy Sladen. Professor E. Ray Lankester, Professor J. Cossar Ewart, Professor M. Foster, Professor S. J. Hickson, and Mr. A. Sedgwick.	100	0	0
To enable Mr. Edgar Allen or other zoologist to investigate the Decapod Crustacea, and Mr. J. J. Lister to work at Foraminifera, at the Laboratory of the Marine Biological Association, Plymouth. [10*l.* renewed.]	*Chairman.*—Mr. G. C. Bourne. *Secretary.* — Professor E. Ray Lankester. Professor M. Foster and Professor S. H. Vines.	20	0	0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
The Zoology, Botany, and Geology of the Irish Sea. [4*l*. 10*s*. 8*d*. renewed.]	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. I. C. Thompson. Professor A. C. Haddon, Professor G. B. Howes, Mr. W. E. Hoyle, Mr. A. O. Walker, Mr. Clement Reid, and Professor F. E. Weiss.	40 0 0
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Dr. A. C. Günther, Dr. D. Sharp, Mr. F. Du Cane Godman, and Professor A. Newton.	50 0 0
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. W. L. Sclater. Dr. P. L. Sclater and Dr. H. Woodward.	50 0 0
Climatology of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Dr. H. R. Mill. Mr. G. J. Symons, Mr. Baldwin Latham, and Mr. H. N. Dickson.	5 0 0
Exploration of Hadramout, Arabia.	*Chairman.*—Mr. H. Seebohm. *Secretary.*—Mr. J. Theodore Bent. Mr. E. G. Ravenstein, Dr. J. G. Garson, and Mr. G. W. Bloxam.	50 0 0
To report on methods of Calibrating the measuring instruments used in Engineering Laboratories, and to take steps for Comparing the Measuring Instruments at present in use in different laboratories.	*Chairman.*—Professor A. B. W. Kennedy. *Secretary.*—Professor W. C. Unwin.	50 0 0
To organise an Ethnographical Survey of the United Kingdom.	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. E. Sidney Hartland. Mr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur J. Evans, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, and Mr. E. G. Ravenstein.	30 0 0
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, and Sir John Evans.	30 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
Anthropometric Measurements in Schools.	*Chairman.*—Professor A. Macalister. *Secretary.*—Professor B. Windle. Mr. E. W. Brabrook, Professor J. Cleland, and Dr. J. G. Garson.	5 0 0
An ancient Kitchen-midden at Hastings already partially examined, and a Settlement called the Wildernesse.	*Chairman.*—Sir John Evans. *Secretary.*—Mr. W. J. Lewis Abbott. Professor Prestwich, Mr. Cuthbert Peek, and Mr. Arthur J. Evans.	10 0 0
To carry out an investigation on the Physiological Applications of the Phonograph, and on the true form of the voice curves made by the instrument.	*Chairman.*—Professor J. G. McKendrick. *Secretary.*—Professor G. G. Murray. Mr. David S. Wingate and Mr. John S. McKendrick.	25 0 0
Corresponding Societies Committee.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Sir Rawson Rawson, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Mr. W. Topley, Professor E. B. Poulton, Mr. Cuthbert Peek, and Rev. Canon H. B. Tristram.	30 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Professor H. McLeod. Professor A. Schuster, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Mr. C. Chree, Mr. G. J. Symons, and Mr. W. E. Wilson.
The Volcanic and Seismological Phenomena of Japan.	*Chairman.*—Lord Kelvin. *Secretary.*—Professor J. Milne. Professor W. G. Adams, Mr. J. T. Bottomley, Professor A. H. Green, and Professor C. G. Knott.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Mr. C. Chree. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Mr. C. H. Carpmael, Professor A. Schuster, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor A. Schuster, Lord Kelvin, the Abbé Renard, Dr. A. Buchan, the Hon. R. Abercromby, Dr. M. Grabham, and Mr. John Aitken.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Professor Edward Hull, Professor J. Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Professor Michie Smith.
That Mr. W. N. Shaw and the Rev. T. C. Fitzpatrick be requested to continue their Report on the present state of our Knowledge in Electrolysis and Electro-chemistry.	—
That Mr. John Brill be requested to draw up a Report on Non-commutative Algebras.	—
The Properties of Solutions . . .	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor W. Ramsay.
Reporting on the Bibliography of Solution.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor H. McLeod, Mr. S. U. Pickering, Professor W. Ramsay, and Professor S. Young.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Action of Light on the Hydracids of the Halogens in presence of Oxygen.	*Chairman.*—Dr. W. J. Russell. *Secretary.*—Dr. A. Richardson. Captain Abney, Professor W. Noel Hartley and Professor W. Ramsay.
To inquire into the Proximate Chemical Constituents of the various kinds of Coal.	*Chairman.*—Sir I. Lowthian Bell. *Secretary.*—Professor P. Phillips Bedson. Professor F. Clowes, Mr. Ludwig Mond, Professors Vivian B. Lewes and E. Hull, and Messrs. J. W. Thomas and H. Bauerman.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
To report on recent Inquiries into the History of Chemistry.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Professor John Ferguson.
The Teaching of Natural Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. George Gladstone, Professor W. R. Dunstan, Sir J. Lubbock, Sir Philip Magnus, Sir H. E. Roscoe, and Dr. Silvanus P. Thompson.
The Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action.	*Chairman.*—Mr. W. Whitaker. *Secretaries.*—Messrs. C. E. De Rance and W. Topley. Messrs. J. B. Redman and J. W. Woodall, Maj.-Gen. Sir A. Clarke, Admiral Sir E. Ommanney, Capt. Sir G. Nares, Capt. J. Parsons, Capt. W. J. L. Wharton, Professor J. Prestwich, Mr. Edward Easton, Mr. J. S. Valentine, and Professor L. F. Vernon Harcourt.
The Volcanic Phenomena of Vesuvius and its neighbourhood.	*Chairman.*—Mr. H. Bauerman. *Secretary.*—Dr. H. J. Johnston-Lavis. Messrs. F. W. Rudler and J. J. H. Teall.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, and Mr. J. E. Marr.
The Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations. And that a Digest of the eighteen Reports should be prepared by the Committee, and sold in a separate form.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. C. E. De Rance. Sir D. Galton, Professor J. Prestwich, and Messrs. J. Glaisher, P. F. Kendall, E. B. Marten, G. H. Morton, I. Roberts, T. S. Stooke, G. J. Symons, W. Topley, C. Tylden-Wright, E. Wethered, and W. Whitaker.
To report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the Fauna, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Professor S. J. Hickson, Professor Riley, Mr. O. Salvin, Dr. P. L. Sclater, and Mr. Edgar A. Smith.
To make a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. W. E. Clarke, and Rev. E. P. Knubley.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Collection of Facts and Statistics bearing on the following Questions:— 1. The influence of previous fertilisation of the female on her subsequent offspring. 2. The effect of maternal impressions during pregnancy on the offspring. The Committee are authorised to communicate with the Councils of the British Medical Society, the Royal Agricultural Society, the Highland Agricultural Society, and the Royal Dublin Society, with the view to joint work.	*Chairman.*—Dr. A. Russel Wallace. *Secretary.*—Dr. James Clark. Professor S. J. Hickson, Professor F. Jeffrey Bell, and Dr. J. N. Langley.
For carrying on the Work of the Anthropometric Laboratory.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Dr. J. G. Garson. Dr. Wilberforce Smith, Professor A. C. Haddon, and Professor B. C. A. Windle.
The Prehistoric and Ancient Remains of Glamorganshire.	*Chairman.*—Dr. C. T. Vachell. *Secretary.*—Mr. E. Seward. Lord Bute, Messrs. G. T. Clark, R. W. Atkinson, Franklen G. Evans, James Bell, and T. H. Thomas, and Dr. J. G. Garson.
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada.	*Chairman.*—Dr. E. B. Tylor. *Secretary.*—Mr. Cuthbert E. Peek. Dr. G. M. Dawson, Mr. R. G. Haliburton, and Mr. H. Hale.
To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the investigation of the Mental and Physical Condition of Children.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. E. W. Brabrook, Dr. J. G. Garson, and Dr. W. Wilberforce Smith.

Communications ordered to be printed in extenso.

Dr. S. P. Langley's paper on 'Recent Researches in the Infra-red Spectrum.'

Professor G. Quincke's paper on the 'Formation of Soap-bubbles by the Contact of Alkaline Oleates with Water.'

Professor W. Förster's paper on the 'Displacements of the Rotational Axis of the Earth.'

Professor A. Cornu's paper on a 'Lecture-room Experiment to illustrate Fresnel's Diffraction Theory, Babinet's Principle.'

Professor J. J. Thomson's paper on the 'Connection between Chemical Combination and the Discharge of Electricity through Gases.'

Mr. H. Brereton Baker's paper on the 'Electrification of Molecules and Chemical Change.'

Professor O. Henrici's report on Planimeters.

Sir Andrew Noble's paper on 'Methods that have been adopted for Measuring Pressures in the Bores of Guns.'

Resolutions relating to the Constitution and Titles of Sections.

That the title of Section B in future be 'Chemistry.'

That the title of Section D be 'Zoology.'

That a separate Section of Botany be established.

That the title of Section I be 'Physiology, including Experimental Pathology and Experimental Psychology.'

That Section I be next constituted independently for the Liverpool Meeting in 1896.

Resolutions referred to the Council for consideration, and action if desirable.

That the Council of the Association be requested to give their full support to the efforts being made to induce the Government to send out a fully-equipped expedition for the exploration of the Antarctic and Southern Seas.

That the Council be requested to call the attention of the Civil Service Commissioners to the report of a Committee of Section F on the *Methods of Economic Training*, and especially to the recommendations (contained on page 2) with regard to the position of Economics in the Civil Service Examinations.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Oxford Meeting, August 1894. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	*s.*	*d.*
*Foster, Professor Carey—Electrical Standards	25	0	0
*Symons, Mr. G. J.—Photographs of Meteorological Phenomena	10	0	0
*Rayleigh, Lord—Mathematical Tables (unexpended balance)	—		
*Symons, Mr. G. J.—Earth Tremors	75	0	0
*McLaren, Lord—Meteorological Observations on Ben Nevis	50	0	0
Atkinson, Dr. E.—Abstracts of Physical Papers	100	0	0
Fox, Mr. Howard—Reduction of Magnetic Observations made at Falmouth Observatory	50	0	0
Rücker, Professor A. W.—Comparison of Magnetic Standards	25	0	0
Harley, Rev. R.—Calculation of Certain Integrals	15	0	0
Thompson, Professor S. P.—Uniformity of Size of Pages of Transactions, &c.	5	0	0

Chemistry.

	£	*s.*	*d.*
*Roscoe, Sir H. E.—Wave-length Tables of the Spectra of the Elements	10	0	0
*Thorpe, Dr. T. E.—Action of Light upon Dyed Colours	5	0	0
*Armstrong, Professor H. E.—Formation of Haloids from Pure Materials	20	0	0
*Tilden, Professor W. A.—Isomeric Naphthalene Derivatives	30	0	0
*Reynolds, Professor J. E.—Electrolytic Quantitative Analysis	40	0	0

Geology.

	£	*s.*	*d.*
*Hull, Professor E.—Erratic Blocks	10	0	0
*Wiltshire, Professor T.—Palæozoic Phyllopoda	5	0	0
*Geikie, Professor J.—Photographs of Geological Interest (renewed)	10	0	0
*Horne, Mr. J.—Shell-bearing Deposits at Clava, &c.	10	0	0
*Traquair, Dr. R. H.—Eurypterids of the Pentland Hills	3	0	0
*Woodward, Mr. H. B.—New Sections of Stonesfield Slate	50	0	0
*Tiddeman, Mr. R. H.—Exploration of Calf-Hole Cave	10	0	0
*Bonney, Professor T. G.—Investigation of a Coral Reef by Boring and Sounding	10	0	0
Evans, Sir John—Nature and Probable Age of High-level Flint-drifts	10	0	0
Green, Professor A. H.—Examination of Locality where the Cetiosaurus in the Oxford Museum was found	20	0	0
Carried forward	£598	0	0

* Reappointed.

	£	s.	d.
Brought forward	598	0	0

Biology.

*Sclater, Dr. P. L.—Investigations at the Zoological Station, Naples	100	0	0
*Bourne, Mr. G. C.—Investigations at the Biological Laboratory, Plymouth (10*l.* renewed)	20	0	0
*Herdman, Professor W. A.—Zoology, Botany, and Geology of the Irish Sea (partly renewed)	40	0	0
*Sclater, Dr. P. L.—Zoology and Botany of the West India Islands	50	0	0
*Flower, Sir W. H.—Index of Genera and Species of Animals	50	0	0

Geography.

*Ravenstein, Mr. E. G.—Climatology of Tropical Africa	5	0	0
*Seebohm, Mr. H.—Exploration of Hadramout	50	0	0

Mechanical Science.

Kennedy, Professor A. B. W.—Calibration and Comparison of Measuring Instruments	50	0	0

Anthropology.

*Brabrook, Mr. E. W.—Ethnographical Survey	30	0	0
*Munro, Dr. R.—Lake Village at Glastonbury	30	0	0
*Macalister, Professor A.—Anthropometric Measurements in Schools	5	0	0
Evans, Sir J.—Exploration of a Kitchen-midden at Hastings	10	0	0

Physiology.

McKendrick, Professor J. G.—Physiological Applications of the Phonograph	25	0	0
*Meldola, Professor R.—Corresponding Societies	30	0	0
	£1,093	0	0

* Reappointed.

The Annual Meeting in 1895.

The Meeting at Ipswich will commence on Wednesday, September 11.

The Annual Meeting in 1896.

The Annual Meeting of the Association in 1896 will be held at Liverpool.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

1834.

	£	s.	d.
Tide Discussions	20	0	0

1835.

	£	s.	d.
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0

1836.

	£	s.	d.
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on Long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0

1837.

	£	s.	d.
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6

1838.

	£	s.	d.
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2

1839.

	£	s.	d.
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	0
Cast-iron Experiments	103	0	7
Railway Constants	28	7	0
Land and Sea Level	274	1	2
Steam-vessels' Engines	100	0	4
Stars in Histoire Céleste	171	18	0
Stars in Lacaille	11	0	6
Stars in R.A.S. Catalogue	166	16	0
Animal Secretions	10	10	6
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0

1840.

	£	s.	d.
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4

1841.

	£	s.	d.
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Firth of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8

	£	s.	d.
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland ...	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells ...	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology.........1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu......	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals......	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh..................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces...	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall .	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York..	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay..............................	100	0	0
Computation of the Gaussian Constants for 1829	5	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain ...	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers..........................	11	7	6
Anemometers' Repairs.........	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854.........£ 75 0 0 1855.........£500 0 0	575	0	0

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860......£50 0 0 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland Coasts	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging, Shetland	75	0	0
Dredging, Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee...............	64	13	4
Balloon Committee	50	0	0
Metrical Committee............	50	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed ...	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation ...	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards............	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast ...	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water........................	50	0	0
Polycyanides of Organic Radicals	29	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania............	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches ...	30	0	0
Palestine Exploration Fund...	100	0	0
	£1750	13	4

1867.

Maintaining the Establishment at Kew Observatory..	600	0	0
Meteorological Instruments, Palestine.........................	50	0	0
Lunar Committee	120	0	0
Metrical Committee............	30	0	0
Kent's Hole Explorations ...	100	0	0
Palestine Explorations.........	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall..................	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed ...	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards............	100	0	0
Ethyl and Methyl Series......	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture ..	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee	120	0	0
Metrical Committee............	50	0	0
Zoological Record...............	100	0	0
Kent's Hole Explorations ...	150	0	0
Steamship Performances	100	0	0
British Rainfall..................	50	0	0
Luminous Meteors..............	50	0	0
Organic Acids	60	0	0
Fossil Crustacea..................	25	0	0
Methyl Series.....................	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall..	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

Maintaining the Establishment at Kew Observatory..	600	0	0
Lunar Committee..................	50	0	0
Metrical Committee...............	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall.................	50	0	0
Thermal Conductivity of Iron, &c..................................	30	0	0
Kent's Hole Explorations......	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron........................	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series.....................	30	0	0
Organic Remains in Limestone Rocks.....................	10	0	0
Earthquakes in Scotland......	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature...	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0

	£	s.	d.
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall	100	0	0
Ohm's Law	9	15	0
Tide Calculating Machine	200	0	0
Specific Volume of Liquids	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	5	0	0
Estimation of Potash and Phosphoric Acid	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record	100	0	0
Kent's Cavern Exploration	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland	1	10	0
Zoological Record	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Naples Zoological Station	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles	13	15	0
Measuring Speed of Ships	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acid in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpeæ, Report on	20	0	0
Mechanical Equivalent of Heat	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperature	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodacetoacetate	10	0	0
British Earthworks	25	0	0
Atmospheric Electricity in India	15	0	0
Development of Light from Coal-gas	20	0	0

	£	s.	d.
Estimation of Potash and Phosphoric Acid	1	18	0
Geological Record	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c.	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record	100	0	0
Investigation of Pulse Phenomena by means of Siphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters	15	0	0
Transmission of Electrical Impulses through Nerve Structure	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee	66	0	0
Chemical Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0

	£	s.	d.
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe	25	0	0
Circulation of Underground Waters	15	0	0
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0

	£	s.	d.
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds .	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station ...	100	0	0
Zoological Literature Record.	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilimanjaro	25	0	0
Recent Polyzoa	10	0	0
Marine Biological Station at Granton	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea...	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.

	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Observations on Ben Nevis ...	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds...	20	0	0
Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Palæozoic Phyllopoda	15	0	0
Zoological Literature Record.	100	0	0
Biological Station, Granton...	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea...	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.

	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant) ...	50	0	0
Cae Gwyn Cave, N. Wales ...	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight...	20	0	0
Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museums Reports	5	0	0
Lymphatic System	25	0	0
Naples Biological Station ...	100	0	0
Plymouth Biological Station	50	0	0

	£	s.	d.
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.

	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0
Naples Zoological Station	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	75	0	0
Electrolysis	20	0	0
Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations	100	0	0
Flora of China	25	0	0
Naples Zoological Station	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands	100	0	0
Geology and Geography of Atlas Range	100	0	0
Action of Waves and Currents in Estuaries	100	0	0
North-Western Tribes of Canada	150	0	0
Nomad Tribes of Asia Minor	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
'Baths Committee,' Bath	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards	12	17	0
Electrolysis	5	0	0
Electro-optics	50	0	0
Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0

	£	s.	d.
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Palæozoic Phyllopoda	10	0	0
Circulation of Underground Waters	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzóa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northamptonshire	25	0	0
Botanical Station at Peradeniya	25	0	0
Experiments with a Tow-net	4	3	9
Naples Zoological Station	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory	50	0	0
Electrical Standards	100	0	0
Electrolysis	5	0	0
Seismological Phenomena of Japan	10	0	0
Temperatures of Lakes	20	0	0
Photographs of Meteorological Phenomena	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for Analysis of Iron and Steel	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	17	10	0
Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Observations on Ben Nevis	150	0	0
Mathematical Tables	15	0	0
Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0

	£	s.	d.
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	30	0	0
	£907	15	6

1894.

	£	s.	d.
Electrical Standards	25	0	0
Photographs of Meteorological Phenomena	10	0	0
Tables of Mathematical Functions	15	0	0
Intensity of Solar Radiation	5	5	6
Wave-length Tables	10	0	0
Action of Light upon Dyed Colours	5	0	0
Erratic Blocks	15	0	0
Fossil Phyllopoda	5	0	0
Shell-bearing Deposits at Clava, &c.	20	0	0
Eurypterids of the Pentland Hills	5	0	0
New Sections of Stonesfield Slate	14	0	0
Observations on Earth-tremors	50	0	0
Exploration of Calf-Hole Cave	5	0	0
Naples Zoological Station	100	0	0
Marine Biological Association	5	0	0
Zoology of the Sandwich Islands	100	0	0
Zoology of the Irish Sea	40	0	0
Structure and Function of the Mammalian Heart	10	0	0
Exploration in Abyssinia	30	0	0
Economic Training	9	10	0
Anthropometric Laboratory Statistics	5	0	0
Ethnographical Survey	10	0	0
The Lake Village at Glastonbury	40	0	0
Anthropometrical Measurements in Schools	5	0	0
Mental and Physical Condition of Children	20	0	0
Corresponding Societies	25	0	0
	£583	15	6

General Meetings.

On Wednesday, August 8, at 8 P.M., in the Sheldonian Theatre, Professor J. S. Burdon Sanderson, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., resigned the office of President to the Most Hon. the Marquis of Salisbury, K.G., D.C.L., F.R.S., Chancellor of the University of Oxford, who took the Chair, and delivered an Address, for which see page 3.

On Thursday, August 9, at 8.30 P.M., a Soirée took place at the Museum.

On Friday, August 10, at 8.30 P.M., in the Sheldonian Theatre, Dr. J. W. Gregory, F.G.S., delivered a discourse on 'Experiences and Prospects of African Exploration.'

On Monday, August 13, at 8.30 P.M., in the Sheldonian Theatre, Professor J. Shield Nicholson, M.A., delivered a discourse on 'Historical Progress and Ideal Socialism.'

On Tuesday, August 14, at 8.30 P.M., a Soirée took place at the New Examination Schools.

On Wednesday, August 15, at 2.30 P.M., in the New Examination Schools, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Ipswich. [The Meeting is appointed to commence on Wednesday, September 11, 1895.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

THE MOST HON. THE MARQUIS OF SALISBURY,

K.G., D.C.L., F.R.S., Chancellor of the University of Oxford,

PRESIDENT.

My functions are of a more complicated character than usually is assigned to the occupants of this Chair. As Chancellor of the University it is my duty to tender to the British Association a hearty welcome, which it is my duty as President of the Association to accept. As President of the Association I convey, most unworthily, the voice of English science, as many worthy and illustrious Presidents have done before me; but in representing the University I represent far more fittingly the learners who are longing to hear the lessons which the first teachers of English science have come as visitors to teach. I am bound to express on behalf of the University our sense of the good feeling towards that body which is the motive of this unusual arrangement. But as far as I am personally concerned, it is attended with some embarrassing results. In presence of the high priests of science I am only a layman, and all the skill of all the chemists the Association contains will not transmute a layman into any more precious kind of metal. Yet it is my hard destiny to have to address on scientific matters probably the most competent scientific audience in the world. If a country gentleman, who was also a colonel of Volunteers, were by any mental aberration on the part of the Commander-in-Chief to be appointed to review an army corps at Aldershot, all military men would doubtless feel a deep compassion for his inevitable fate. I bespeak some spark of that divine emotion when I am attempting to discharge under similar conditions a scarcely less hopeless duty. At least, however, I have the consolation of feeling that I am free from some of the anxieties which have fallen to those who have preceded me as Presidents in this city. The relations of the Association and the University are those of entire sympathy and good will, as becomes common workers in the sacred cause of diffusing enlightenment and knowledge. But we must admit that it was not always so. A curious record of a very different state of feeling came to light last year in the interesting biography of Dr. Pusey, which is the posthumous work of Canon Liddon. In it is related the first visit of the Association to Oxford in 1832. Mr. Keble, at that time a leader of University thought, writes indignantly to his friend to complain that the honorary degree of D.C.L. had been bestowed upon some of the most distinguished members of the Association : 'The Oxford Doctors,' he says, 'have truckled sadly to the spirit of the times in receiving the hodge-podge of philosophers as they did.' It is amusing, at this distance of time, to note the names of the hodge-podge of philosophers whose academical distinctions so sorely vexed Mr. Keble's gentle spirit. They were Brown, Brewster, Faraday, and Dalton. When we recollect the lovable and serene character of Keble's nature, and that he was at that particular date probably the man in the University who had the greatest power over other men's minds, we can measure the distance we have traversed since that time ; and the rapidity with which the converging paths of these two intellectual luminaries, the University and the Association, have approximated to each other. This sally of Mr. Keble's was no passing or accidental caprice. It represented a deep-seated sentiment in this place of learning, which had its origin in historic causes, and which has only died out in our time. One potent cause of it was that both bodies were teachers of science, but did not then in any degree attach the same meaning to that word. Science with the University for many generations bore a signification different from that which belongs to it in this assembly. It represented the knowledge which alone in the Middle Ages was thought worthy of the name of science. It was the knowledge gained not by external observation, but by mere reflection. The student's microscope was turned inward upon the recesses of his own brain ; and when the supply of facts and realities failed, as it very speedily did, the scientific imagination was not wanting to furnish to successive generations an interminable series of conflicting speculations. *That* science—science in our academical sense—had its day of rapid growth, of boundless aspiration, of enthusiastic votaries. It fascinated the rising intellect of the time, and it is said—people were not particular about figures in those days—that its attractions were at one time potent enough to gather round the University thirty thousand students, who for the sake of learning its teaching were willing to endure a life of the severest hardship. Such a state of feeling is now an archæological curiosity. The revolt against Aristotle is now some three centuries old. But the mental sciences which were supposed to rest upon his writings have retained some of their ascendency even till this day, and have only slowly and jealously admitted the rivalry of the growing sciences of observation. The subject is interesting to us, as this undecided state of feeling coloured the experiences of this Association at its last Oxford visit, nearly a generation later, in 1860. The warmth of the encounters which then took place have left a vivid impression on the minds of those who are old enough to have witnessed them. That much energy was on that occasion converted into heat may, I think, be inferred from the mutual distance which the two bodies have since maintained. Whereas the visit of 1832 was succeeded by another visit in fifteen years, and the visit of 1847 was succeeded by another visit in thirteen years, the year 1860 was followed by a long and dreary interval of separation, which has only now, after four-and-thirty years, been terminated. It has required the lapse of a generation to draw the curtain of oblivion over those animated scenes. It was popularly supposed that deep divergences upon questions of religion were the motive force of those high controversies. To some extent that impression was correct. But men do not always discern the motives which are really urging them, and I suspect that in many cases religious apprehensions only masked the resentment of the older learning at the appearance and claims of its younger rival. In any case there is something worthy of note, and something that conveys encouragement, in the difference of the feeling which prevails now and the feeling that was indicated then. Few men are now influenced by the strange idea that questions of religious belief depend on the issues of physical research. Few men, whatever their creed, would now seek their geology in the books of their religion, or, on the other hand, would fancy that the laboratory or the microscope could help them to penetrate the mysteries which hang over the nature and the destiny of the soul of man. And the old learning no longer contests the share in education which is claimed by the new, or is blind to the supreme influence which natural knowledge is exercising in moulding the human mind.

A study of the addresses of my learned predecessors in this office shows me that the main duty which it falls to a President to perform in his introductory address, is to remind you of the salient points in the annals of science since last the Association visited the town in which he is speaking. Most of them have been able to lay before you in all its interesting detail the history of the particular science of which each one of them was the eminent representative. If I were to make any such attempt I should only be telling you with very inadequate knowledge a story which is from time to time told you, as well as it can be told, by men who are competent to deal with it. It will be more suitable to my capacity if I devote the few observations I have to make to a survey not of our science but of our ignorance. We live in a small bright oasis of knowledge surrounded on all sides by a vast unexplored region of impenetrable mystery. From age to age the strenuous labour of successive generations wins a small strip from the desert and pushes forward the boundary of knowledge. Of such triumphs we are justly proud. It is a less attractive task--but yet it has its fascination as well as its uses—to turn our eyes to the undiscovered country which still remains to be won, to some of the stupendous problems of natural study which still defy our investigation. Instead, therefore, of recounting to you what has been done, or trying to forecast the discoveries of the future, I would rather draw your attention to the condition in which we stand towards three or four of the most important physical questions which it has been the effort of the last century to solve.

Of the scientific enigmas which still, at the end of the nineteenth century, defy solution, the nature and origin of what are called the elements is the most notable. It is not, perhaps, easy to give a precise logical reason for the feeling that the existence of our sixty-five elements is a strange anomaly and conceals some much simpler state of facts. But the conviction is irresistible. We cannot conceive, on any possible doctrine of cosmogony, how these sixty-five elements came into existence. A third of them form the substance of this planet. Another third are useful, but somewhat rare. The remaining third are curiosities scattered haphazard, but very scantily, over the globe, with no other apparent function but to provide occupation for the collector and the chemist. Some of them are so like each other that only a chemist can tell them apart: others differ immeasurably from each other in every conceivable particular. In cohesion, in weight, in conductivity, in melting-point, in chemical proclivities they vary in every degree. They seem to have as much relation to each other as the pebbles on a sea beach, or the contents of an ancient lumber room. Whether you believe that Creation was the work of design or of inconscient law, it is equally difficult to imagine how this random collection of dissimilar materials came together. Many have been the attempts to solve this enigma; but up till now they have left it more impenetrable than before. A conviction that here was something to discover lay beneath the persistent belief in the possibility of the transmutation of other metals into gold, which brought the alchemy of the Middle Ages into being. When the immortal discovery of Dalton established that the atoms of each of these elements have a special weight of their own, and that consequently they combine in fixed ponderable proportions from which they never depart, it renewed the hope that some common origin of the elements was in sight. The theory was advanced that all these weights were multiples of the weight of hydrogen—in other words, that each elementary atom was only a greater or a smaller number of hydrogen atoms compacted by some strange machinery into one. The most elaborate analyses, conducted by chemists of the highest eminence—conspicuously by the illustrious Stas—were directed to the question whether there was any trace in fact of the theoretic idea that the atoms of each element consist of so many atoms or even of so many half-atoms of hydrogen. But the reply of the laboratories has always been clear and certain—that there is not in the facts the faintest foundation for such a theory.

Then came the discovery of the spectral analysis, and men thought that with an instrument of such inconceivable delicacy we should at last find out something as to the nature of the atom. The result has been wholly disappointing. Spectral analysis in the hands of Dr. Huggins and Mr. Lockyer and others has taught us things of which the world little expected to be told. We have been enabled to measure the speed with which clouds of blazing hydrogen course across the surface of the sun:

we have learnt the pace—the fabulous pace—at which the most familiar stars have been for ages approaching to or receding from our planet, without apparently affecting the proportions of the patterns which as far as historical record goes back they have always delineated on the evening sky. We have received some information about the elementary atoms themselves. We have learnt that each sort of atom when heated strikes upon the ether a vibration, or set of vibrations, whose rate is all its own; and that no one atom or combination of atoms in producing its own spectrum encroaches even to the extent of a single line upon the spectrum that is peculiar to its neighbour. We have learnt that the elements which exist in the stars and specially in the sun are mainly those with which we are familiar upon earth. There are a few lines in excess to which we can give no terrestrial name; and there are some still more puzzling gaps in our list. It is a great aggravation of the mystery which besets the question of the elements, that among the lines which are absent from the spectrum of the sun, those of nitrogen and oxygen stand first. Oxygen constitutes the largest portion of the solid and liquid substance of our planet, so far as we know it; and nitrogen is very far the predominant constituent of our atmosphere. If the earth is a detached bit whirled off the mass of the sun, as cosmogonists love to tell us, how comes it that in leaving the sun we cleaned him out so completely of his nitrogen and oxygen that not a trace of these gases remains behind to be discovered even by the sensitive vision of the spectroscope?

All these things the discovery of spectrum analysis has added to our knowledge; but it has left us as ignorant as ever as to the nature of the capricious differences which separate the atoms from each other, or the cause to which those differences are due.

In the last few years the same enigma has been approached from another point of view by Mr. Newlands and Professor Mendeléeff. The periodic law which they have discovered reflects on them all the honour that can be earned by ingenious, laborious, and successful research. The Professor has shown that this perplexing list of elements can be divided into families of about seven, speaking very roughly: that those families all resemble each other in this, that as to weight, volume, heat, and laws of combination the members of each family are ranked among themselves in obedience to the same rule. Each family differs from the others; but each internally is constructed upon the same plan. It was a strange discovery—strangest of all in its manifest defects. For in the plan of his families there were blanks left; places not filled up because the properly constituted elements required according to his theory had not been found to fill them. For the moment their absence seemed a weakness in the Professor's idea, and gave an arbitrary aspect to his scheme. But the weakness was turned into strength when, to the astonishment of the scientific world, three of the elements which were missing made their appearance in answer to his call. He had described beforehand the qualities they ought to have; and gallium, germanium, and scandium, when they were discovered shortly after the publication of his theory, were found to be duly clothed with the qualities he required in each. This remarkable confirmation has left Mendeléeff's periodic law in an unassailable position. But it has rather thickened than dissipated the mystery which hangs over the elements. The discovery of these co-ordinate families dimly points to some identical origin, without suggesting the method of their genesis or the nature of their common parentage. If they were organic beings all our difficulties would be solved by muttering the comfortable word 'evolution'—one of those indefinite words from time to time vouchsafed to humanity, which have the gift of alleviating so many perplexities and masking so many gaps in our knowledge. But the families of elementary atoms do not breed; and we cannot therefore ascribe their ordered difference to accidental variations perpetuated by heredity under the influence of natural selection. The rarity of iodine, and the abundance of its sister chlorine, cannot be attributed to the survival of the fittest in the struggle for existence. We cannot account for the minute difference which persistently distinguishes nickel from cobalt, by ascribing it to the recent inheritance by one of them of an advantageous variation from the parent stock.

The upshot is that all these successive triumphs of research, Dalton's, Kirchhoff's, Mendeléeff's, greatly as they have added to our store of knowledge, have gone but little way to solve the problem which the elementary atoms have for centuries presented to mankind. What the atom of each element is, whether it is a movement, or a thing, or a vortex, or a point having inertia, whether there is any limit to its divisibility, and, if so, how that limit is imposed, whether the long list of elements is final, or whether any of them have any common origin, all these questions remain surrounded by a darkness as profound as ever. The dream which lured the alchemists to their tedious labours, and which may be said to have called chemistry into being, has assuredly not been realised, but it has not yet been refuted. The boundary of our knowledge in this direction remains where it was many centuries ago.

The next discussion to which I should look in order to find unsolved riddles which have hitherto defied the scrutiny of science, would be the question of what is called the ether. The ether occupies a highly anomalous position in the world of science. It may be described as a half-discovered entity. I dare not use any less pedantic word than entity to designate it, for it would be a great exaggeration of our knowledge if I were to speak of it as a body or even as a substance. When nearly a century ago Young and Fresnel discovered that the motions of an incandescent particle were conveyed to our eyes by undulation, it followed that between our eyes and the particle there must be something to undulate. In order to furnish that something, the notion of the ether was conceived, and for more than two generations the main, if not the only, function of the word ether has been to furnish a nominative case to the verb 'to undulate.' Lately, our conception of this entity has received a notable extension. One of the most brilliant of the services which Professor Maxwell has rendered to science has been the discovery that the figure which expressed the velocity of light also expressed the multiplier required to change the measure of static or passive electricity into that of dynamic or active electricity. The interpretation reasonably affixed to this discovery is that, as light and the electric impulse move approximately at the same rate through space, it is probable that the undulations which convey them are undulations of the same medium. And as induced electricity penetrates through everything, or nearly everything, it follows that the ether through which its undulations are propagated must pervade all space, whether empty or full, whether occupied by opaque matter or transparent matter, or by no matter at all. The attractive experiments by which the late Professor Herz illustrated the electric vibrations of the ether will only be alluded to by me in order that I may express the regret deeply and generally felt that death should have terminated prematurely the scientific career which had begun with such brilliant promise and such fruitful achievements. But the mystery of the ether, though it has been made more fascinating by these discoveries, remains even more inscrutable than before. Of this all-pervading entity we know absolutely nothing except this one fact, that it can be made to undulate. Whether, outside the influence of matter on the motion of its waves, ether has any effect on matter or matter upon it, is absolutely unknown. And even its solitary function of undulating, ether performs in an abnormal fashion which has caused infinite perplexity. All fluids that we know transmit any blow they have received by waves which undulate backwards and forwards in the path of their own advance. The ether undulates athwart the path of the wave's advance. The genius of Lord Kelvin has recently discovered what he terms a labile state of equilibrium, in which a fluid that is infinite in its extent may exist, and may undulate in this eccentric fashion without outraging the laws of mathematics. I am no mathematician, and I cannot judge whether this reconciliation of the action of the ether with mechanical law is to be looked upon as a permanent solution of the question, or is only what diplomatists call a *modus vivendi*. In any case it leaves our knowledge of the ether in a very rudimentary condition. It has no known qualities except one, and that quality is in the highest degree anomalous and inscrutable. The extended conception which enables us to recognise ethereal waves in the vibrations of electricity has added infinite attraction to the study of those waves, but it carries its own difficulties with it. It is not easy to fit in the theory of electrical ether waves with the phenomena of positive and negative electricity, and as to the true significance and cause of those counteracting and complementary forces, to which we give the provisional names of negative and positive, we know about as much now as Franklin knew a century and a half ago.

I have selected the elementary atoms and the ether as two instances of the obscurity that still hangs over problems which the highest scientific intellects have been investigating for several generations. A more striking but more obvious instance still is Life—animal and vegetable Life—the action of an unknown force on ordinary matter. What is the mysterious impulse which is able to strike across the ordinary laws of matter, and twist them for a moment from their path? Some people demur to the use of the term 'vital force' to designate this impulse. In their view the existence of such a force is negatived by the fact that chemists have been able by cunning substitutions to produce artificially the peculiar compounds which in nature are only found in organisms that are or have been living. These compounds are produced by some living organism in the performance of the ordered series of functions proper to its brief career. To counterfeit them—as has been done in numerous cases—does not enable us to do what the vital force alone can effect—to bring the organism itself into existence, and to cause it to run its appointed course of change. This is the unknown force which continues to defy not only our imitation but our scrutiny. Biology has been exceptionally active and successful during the last half-century. Its triumphs have been brilliant, and they have been rich enough not only in immediate result but in the promise of future advance. Yet they give at present no hope of penetrating the great central mystery. The progress which has been made in the study of microscopic life has been very striking, whether or not the results which are at present inferred from it can be taken as conclusive. Infinitesimal bodies found upon the roots of plants have the proud office of capturing and taming for us the free nitrogen of the air, which, if we are to live at all, we must consume and assimilate, and yet which, without the help of our microscopic ally, we could not draw for any useful purpose from the ocean of nitrogen in which we live. Microscopic bodies are convicted of causing many of the worst diseases to which flesh is heir, and the guilt of many more will probably be brought home to them in due time; and they exercise a scarcely less sinister or less potent influence on our race by the plagues with which they destroy some of the most valuable fruits of husbandry, such as the potato, the mulberry, and the vine. Almost all their power resides in the capacity of propagating their kind with infinite rapidity, and up to this time science has been more skilful in describing their ravages than in devising means to hinder them. It would be ungrateful not to mention two brilliant exceptions to this criticism. The antiseptic surgery which we owe chiefly to Lister; and the inoculation against anthrax, hydrophobia, and perhaps some other diseases, which we owe to Pasteur, must be recorded as splendid victories over the countless legions of our infinitesimal foes. Results like these are the great glory of the scientific workers of the past century. Men may, perhaps, have overrated the progress of nineteenth-century research in opening the secrets of nature; but it is difficult to overrate the brilliant service it has rendered in ministering to the comforts and diminishing the sufferings of mankind.

If we are not able to see far into the causes and origin of life in our own day, it is not probable that we shall deal more successfully with the problem as it arose many million years ago. Yet certainly the most conspicuous event in the scientific annals of the last half-century has been the publication of Mr. Darwin's work on the 'Origin of Species,' which appeared in 1859. In some respects, in the depth of the impression which it made on scientific thought, and even on the general opinion of the world, its momentous effect can hardly be overstated. But at this distance of time it is possible to see that some of its success has been due to adventitious circumstances. It has had the chance of enlisting among its champions some of the most powerful intellects of our time, and perhaps the still happier fortune of appearing at a moment when it furnished an armoury of weapons to men, who were not scientific, for use in the bitter but transitory polemics of the day. But far the largest part of its accidental advantages was to be found in the remarkable character and qualifications of its author. The equity of judgment, the simple-minded love of truth and the patient devotion to the pursuit of it through years of toil and of other conditions the most unpropitious—these things endeared to numbers of men everything that came from Charles Darwin apart from its scientific merit or literary charm. And whatever final value may be assigned to his doctrine, nothing can ever detract from the lustre shed upon it by the wealth of his knowledge and the infinite ingenuity of his resource. The intrinsic power of his theory is shown at least in this one respect, that in the department of knowledge with which it is concerned it has effected an entire revolution in the methods of research. Before his time the study of living nature had a tendency to be merely statistical; since his time it has become predominantly historical. The consideration how an organic body came to be what it is occupies a far larger area in any inquiry now than the mere description of its actual condition; but this question was not predominant—it may almost be said to have been ignored—in the Botanical and Zoological study of sixty years ago.

Another lasting and unquestioned effect has resulted from Darwin's work. He has, as a matter of fact, disposed of the doctrine of the immutability of species. It has been mainly associated in recent days with the honoured name of Agassiz, but with him has disappeared the last defender of it who could claim the attention of the world. Few now are found to doubt that animals separated by differences far exceeding those that distinguish what we know as species have yet descended from common ancestors. But there is much less agreement as to the extent to which this common descent can be assumed, or the process by which it has come about. Darwin himself believed that all animals were descended from 'at most four or five progenitors'—adding that 'there was grandeur in the view that life had been originally breathed by the Creator into a few forms or one.' Some of his more devoted followers, like Professor Haeckel, were prepared to go a step farther and to contemplate primeval mud as the probable ancestor of the whole fauna and flora of this planet.

To this extent the Darwinian theory has not effected the conquest of scientific opinion ; and still less is there any unanimity in the acceptance of natural selection as the sole or even the main agent of whatever modifications may have led up to the existing forms of life. The deepest obscurity still hangs over the origin of the infinite variety of life. Two of the strongest objections to the Darwinian explanation appear still to retain all their force.

I think Lord Kelvin was the first to point out that the amount of time required by the advocates of the theory for working out the process they had imagined could not be conceded without assuming the existence of a totally different set of natural laws from those with which we are acquainted. His view was not only based on profound mechanical reasoning, but it was so plain that any layman could comprehend it. Setting aside arguments deduced from the resistance of the tides, which may be taken to transcend the lay understanding, his argument from the refrigeration of the earth requires little science to apprehend it. Everybody knows that hot things cool, and that according to their substance they take more or less time in cooling. It is evident from the increase of heat as we descend into the earth, that the earth is cooling, and we know by experiment, within certain wide limits, the rate at which its substances, the matters of which it is constituted, are found to cool. It follows that we can approximately calculate how hot it was so many million years ago. But if at any time it was hotter at the surface by 50° F. than it is now, life would then have been impossible upon the planet, and therefore we can without much difficulty fix a date before which organic life on earth cannot have existed. Basing himself on these considerations Lord Kelvin limited the period of organic life upon the earth to a hundred million years, and Professor Tait in a still more penurious spirit cut that hundred down to ten. But on the other side of the account stand the claims of the geologists and biologists. They have revelled in the prodigality of the ciphers which they put at the end of the earth's hypothetical life. Long cribbed and cabined within the narrow bounds of the popular chronology, they have exulted wantonly in their new freedom. They have lavished their millions of years with the open hand of a prodigal heir indemnifying himself by present extravagance for the enforced self-denial of his youth. But it cannot be gainsaid that their theories require at least all this elbowroom. If we think of that vast distance over which Darwin conducts us from the jelly-fish lying on the primeval beach to man as we know him now ; if we reflect that the prodigious change requisite to transform one into the other is made up of a chain of generations, each advancing by a minute variation from the form of its predecessor, and if we further reflect that these successive changes are so minute that in the course of our historical period—say three thousand years—this progressive variation has not advanced by a single step perceptible to our eyes, in respect to man or the animals and plants with which man is familiar, we shall admit that for a chain of change so vast, of which the smallest link is longer than our recorded history, the biologists are making no extravagant claim when they demand at least many hundred million years for the accomplishment of the stupendous process. Of course, if the mathematicians are right, the biologists cannot have what they demand. If, for the purposes of their theory, organic life must have existed on the globe more than a hundred million years ago, it must, under the temperature then prevailing, have existed in a state of vapour. The jelly-fish would have been dissipated in steam long before he had had a chance of displaying the advantageous variation which was to make him the ancestor of the human race. I see, in the eloquent discourse of one of my most recent and most distinguished predecessors in this chair, Sir Archibald Geikie, that the controversy is still alive. The mathematicians sturdily adhere to their figures, and the biologists are quite sure the mathematicians must have made a mistake. I will not get myself into the line of fire by intervening in such a controversy. But until it is adjusted the laity may be excused for returning a verdict of 'not proven' upon the wider issues the Darwinian school has raised.

The other objection is best stated in the words of an illustrious disciple of Darwin, who has recently honoured this city by his presence—I refer to Professor Weismann. But in referring to him, I cannot but give, in passing, a feeble expression to the universal sorrow with which in this place the news was received that Weismann's distinguished antagonist, Professor Romanes, had been taken from us in the outset and full promise of a splendid scientific career.

The gravest objection to the doctrine of natural selection was expressed by Weismann in a paper published a few months ago, not as agreeing to the objection, but as resisting it; and therefore his language may be taken as an impartial statement of the difficulty. 'We accept natural selection,' he says, 'not because we are able to demonstrate the process in detail, not even because we can with more or less ease imagine it, but simply because we must—because it is the only possible explanation that we can conceive. We must assume natural selection to be the principle of the explanation of the metamorphoses, because all other apparent principles of explanation fail us, and it is inconceivable that there could yet be another capable of explaining the adaptation of organisms without assuming the help of a principle of design.'

There is the difficulty. We cannot demonstrate the process of natural selection in detail; we cannot even, with more or less ease, imagine it. It is purely hypothetical. No man, so far as we know, has ever seen it at work. An accidental variation may have been perpetuated by inheritance, and in the struggle for existence the bearer of it may have replaced, by virtue of the survival of the fittest, his less improved competitors; but as far as we know no man or succession of men have ever observed the whole process in any single case, and certainly no man has recorded the observation. Variation by *artificial* selection, of course, we know very well; but the intervention of the cattle breeder and the pigeon fancier is the essence of artificial selection. It is effected by their action in crossing, by their skill in bringing the right mates together to produce the progeniture they want. But in natural selection who is to supply the breeder's place? Unless the crossing is properly arranged, the new breed will never come into being. What is to secure that the two individuals of opposite sexes in the primeval forest, who have been both accidentally blessed with the same advantageous variation, shall meet, and transmit by inheritance that variation to their successors? Unless this step is made good, the modification will never get a start; and yet there is nothing to insure that step, except pure chance. The law of chances takes the place of the cattle breeder and the pigeon fancier. The biologists do well to ask for an immeasurable expanse of time, if the occasional meetings of advantageously varied couples from age to age are to provide the pedigree of modifications which unite us to our ancestor the jelly-fish. Of course the struggle for existence, and the survival of the fittest, would in the long run secure the predominance of the stronger breed over the weaker. But it would be of no use in setting the improved breed going. There would not be time. No possible variation which is known to our experience, in the short time that elapses in a single life between the moment of maturity and the age of reproduction, could enable the varied individual to clear the field of all competitors, either by slaughtering or starving them out. But unless the struggle for existence took this summary and internecine character, there would be nothing but mere chance to secure that the advantageously varied bridegroom at one end of the wood should meet the bride, who by a happy contingency had been advantageously varied in the same direction at the same time at the other end of the wood. It would be a mere chance if they ever knew of each other's existence—a still more unlikely chance that they should resist on both sides all temptations to a less advantageous alliance. But unless they did so, the new breed would never even begin, let alone the question of its perpetuation after it had begun. I think Professor Weismann is justified in saying that we cannot, either with more or less ease, imagine the process of natural selection.

It seems strange that a philosopher of Professor Weismann's penetration should accept as established a hypothetical process the truth of which he admits that he cannot demonstrate in detail, and the operation of which he cannot even imagine. The reason that he gives seems to me instructive of the great danger scientific research is running at the present time—the acceptance of mere conjecture in the name and place of knowledge, in preference to making frankly the admission that no certain knowledge can be attained. 'We accept natural selection,' he says, 'because we must—because it is the only possible explanation that we can conceive.' As a politician, I know that argument very well. In political controversy it is sometimes said of a disputed proposal that it 'holds the field,' that it must be accepted because no possible alternative has been suggested. In politics there is occasionally a certain validity in the argument, for it sometimes happens that some definite course must be taken, even though no course is free from objection. But such a line of reasoning is utterly out of place in science. We are under no obligation to find a theory, if the facts will not provide a sound one. To the riddles which nature propounds to us the profession of ignorance must constantly be our only reasonable answer. The cloud of impenetrable mystery hangs over the development and still more over the origin of life. If we strain our eyes to pierce it, with the foregone conclusion that some solution is and must be attainable, we shall only mistake for discoveries the figments of our own imagination. Professor Weismann adds another reason for his belief in natural selection which is certainly characteristic of the time in which we live. 'It is inconceivable,' he says, 'that there should be another principle capable of explaining the adaptation of organisms without assuming the help of a principle of design.' The whirligig of time assuredly brings its revenges. Time was, not very long ago, when the belief in creative design was supreme. Even those who were sapping its authority were wont to pay it a formal homage, fearing to shock the public conscience by denying it. Now the revolution is so complete that a great philosopher uses it as a *reductio ad absurdum*, and prefers to believe that which can neither be demonstrated in detail, nor imagined, rather than run the slightest risk of such a heresy.

I quite accept the Professor's dictum that if natural selection is rejected we have no resource but to fall back on the mediate or immediate agency of a principle of design. In Oxford, at least, he will not find that argument is conclusive, nor, I believe, among scientific men in this country generally, however imposing the names of some whom he may claim for that belief. I would rather lean to the conviction that the multiplying difficulties of the mechanical theory are weakening the influence it once had acquired. I prefer to shelter myself in this matter behind the judgment of the greatest living master of natural science among us, Lord Kelvin, and to quote as my own concluding words the striking language with which he closed his address from this chair more than twenty years ago: 'I have always felt,' he said, 'that the hypothesis of natural selection does not contain the true theory of evolution, if evolution there has been in biology. ... I feel profoundly convinced that the argument of design has been greatly too much lost sight of in recent zoological speculations. Overpoweringly strong proofs of intelligent and benevolent design lie around us, and if ever perplexities, whether metaphysical or scientific, turn us away from them for a time, they come back upon us with irresistible force, showing to us through nature the influence of a free will, and teaching us that all living things depend on one everlasting Creator and Ruler.'

REPORTS

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Corresponding Societies.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), Mr. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Sir DOUGLAS GALTON, Sir RAWSON RAWSON, Mr. G. J. SYMONS, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Professor T. G. BONNEY, Mr. W. WHITAKER, Mr. W. TOPLEY, Professor E. B. POULTON, Mr. CUTHBERT PEEK, *and* Rev. Canon H. B. TRISTRAM.

THE Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following report of the proceedings of the Conferences held at Nottingham and at Oxford.

The Council nominated Dr. J. G. Garson, Chairman, Mr. G. J. Symons, Vice-Chairman, and Mr. T. V. Holmes, Secretary to the Nottingham Conference. These nominations were confirmed by the General Committee at the meeting held at Nottingham on Wednesday, September 13. The meetings of the Conference were held on Thursday, September 14, and on Tuesday, September 19, in University College, Nottingham, at 3.30 P.M. The following Corresponding Societies nominated delegates to represent them at the Nottingham meeting:—

Bath Natural History and Antiquarian Field Club.	Rev. H. H. Winwood, M.A., F.G.S.
Belfast Natural History and Philosophical Society.	Alexander Tate.
Birmingham Natural History and Microscopical Society.	C. J. Watson.
Birmingham Philosophical Society . .	J. Kenward, F.S.A.
Bristol Naturalists' Society	Dr. A. Richardson.
Burton-on-Trent Natural History and Archæological Society.	Horace T. Brown, F.R.S.
Cardiff Naturalists' Society	Prof. J. Viriamu Jones.
Chesterfield and Midland Counties Institution of Engineers.	M. H. Mills, F.G.S.

Croydon Microscopical and Natural History Club.	W. Topley, F.R.S.
Dorset Natural History and Antiquarian Field Club.	C. Hansford.
East Kent Natural History Society . East of Scotland Union of Naturalists' Societies.	A. S. Reid, M.A., F.G.S.
Essex Field Club	T. V. Holmes, F.G.S.
Federated Institution of Mining Engineers.	M. H. Mills, M.Inst.C.E.
Hampshire Field Club	W. Whitaker, B.A., F.R.S.
Hertfordshire Natural History Society and Field Club.	Dr. A. T. Brett.
Leeds Geological Association	P. F. Kendall, F.G.S.
Leeds Naturalists' Club	Harold Wager.
Leicester Literary and Philosophical Society.	F. T. Mott, F.R.G.S.
Liverpool Geological Society	E. Dickson, F.G.S.
Liverpool Engineering Society . . .	H. P. Boulnois, M.Inst.C.E.
Malton Naturalists' Society	M. B. Slater.
Manchester Geographical Society . . .	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society . . .	Mark Stirrup, F.G.S.
North of England Institute of Mining Engineers.	Prof. J. H. Merivale, M.A.
North Staffordshire Naturalists' Field Club.	Dr. J. T. Arlidge.
Northamptonshire Natural History Society and Field Club.	C. A. Markham, F.R.Met.Soc.
Nottingham Naturalists' Society . .	J. W. Carr, M.A. W. Stafford, M.B. C. Hawley Torr.
Nottingham Technical Schools . . .	Prof. W. Robinson, M.E.
Paisley Philosophical Institution . .	James Clark.
Perthshire Society of Natural Science .	A. S. Reid, M.A., F.G.S.
Rochdale Literary and Scientific Society	H. C. March, M.D., F.S.A.
Somersetshire Archæological and Natural History Society.	F. T. Elworthy.
South London Microscopical and Natural History Society.	F. W. Hembry.
Tyneside Geographical Society . . .	G. E. T. Smithson, F.R.G.S.
Warwickshire Naturalists' and Archæologists' Field Club.	W. Andrews, F.G.S.
Woolhope Naturalists' Field Club . .	Rev. J. O. Bevan, M.A.
Yorkshire Naturalists' Union	M. B. Slater.

NOTTINGHAM, FIRST CONFERENCE, SEPTEMBER 14, 1893.

The Corresponding Societies Committee were represented by Dr. Garson (in the chair), Mr. Topley, Mr. Symons, and Mr. T. V. Holmes (Secretary).

Dr. Garson, the Chairman, gave a hearty welcome to the delegates present. He stated that these Conferences were begun at Aberdeen in 1885. At that time only twenty-four delegates were appointed, while last year there were forty-two. The number of Corresponding Societies had also increased. This was evidence that the attempt to bring to a focus, as it were, the efforts of the various Corresponding Societies had met with considerable success. But there was also evidence that the Societies did not always sufficiently value their privileges. When the annual returns were sent out from the office of the British Association the majority of the Secretaries of the Corresponding Societies did not fill up and return them until they were written to a second time. Again, out of more than sixty Societies, only forty-two thought it worth while to nominate delegates, though it could hardly be a difficult matter to find members able and willing to serve. It was a very great advantage to the workers in the various local Societies to have the titles of their papers printed and published in the Annual Reports of the British Association. The Transactions of the various Corresponding Societies were bound and kept available for reference at present in the Office of the Association at Burlington House, whereas papers read before other local Societies were not unlikely to remain unknown or unconsulted. It was most desirable that the British Association should be brought into closer communication with the Societies. It had been usual hitherto for representatives from the different Sections to attend the Conferences and to mention anything that had been done, such as the appointment of a committee for some special purpose, in which the co-operation of the Corresponding Societies would be advantageous. It would be a good thing that there should be better means of communication between the Corresponding Societies and the Secretaries of the various committees appointed by the British Association. A good example of a committee especially needing the assistance of the Corresponding Societies was that nominated by Section H to make an Ethnographical Survey of the United Kingdom. The first Report of this committee had just been presented to the delegates, and Mr. Brabrook, the Secretary, would shortly call their attention to it. At their last meeting at Edinburgh some delegates had asked whether the Council of the Association might not be able to obtain greater facilities from the railway companies for members travelling to and from these meetings. The Council consequently appointed a committee, of which Sir Frederick Bramwell was an active member, to see what could be done. The result, however, could not be deemed satisfactory. The Clearing House authorities considered that the ordinary tourists' tickets met the requirements of the case, and reminded them that return tickets were issued to members at a single fare for distances not exceeding fifty miles from the place of meeting. The local authorities had placed the room in which they then were at the disposal of the delegates, and in it they might meet to discuss matters at any time.

The Secretary read a letter from Sir Douglas Galton, expressing his regret at being unable to attend the Conference.

The Chairman proposed to take the Report which was in their hands as read. He would be glad to hear any remarks from delegates on the work done during the past year.

SECTION A.

Meteorological Photography.—Mr. Symons was much indebted to the delegates for the number of photographs of clouds sent in to the Committee up to the present time. He did not press for more, as the Committee appointed by the British Association for the 'Elucidation of Meteorological Phenomena by the Application of Photography' had the very considerable collection of 467 to deal with. They proposed to select the typical ones, reduce them to a uniform scale, and print perhaps a hundred copies of them. They hoped to publish the atlas during the year, and would be glad if the meteorologists would take copies. They would be pleased to have additional photographs of lightning.

Mr. Kenward remarked that through the agency of the standing Meteorological Committee of the Birmingham Philosophical Society complete weather statistics for Birmingham had been obtained from the observatory in Monument Road. It was believed that the periodical publication of these records would supply a great want.

SECTION C.

Mr. A. S. Reid said that the Geological Photographs Committee of the British Association were publishing their fourth Report this year. During the year they had received more than forty new photographs, making the total collection 846: they were all British. Their appeal to the Corresponding Societies had been more successful than in any previous year, but there was still much to be done, and he hoped the delegates would stir up their Societies on this point. As to the best camera, the most portable was to be preferred. He had also to report that many prints had been sent in without the name of the Societies sending them, that of the photographer, or that of the place photographed. They had decided not to lend any more photographs to the Societies, unless such photographs were sent in duplicate. Mr. Jeffs, the Secretary of the Geological Photographs Committee, had unfortunately been ill during nearly the whole of the year, and this had seriously hampered their work.

Mr. Tate said that, with reference to geological photographs, many of those sent in were probably of little value. He trusted that some day the Geological Photographs Committee would be able to select typical examples and place them where they would be of use to the Corresponding Societies. Some had been sent from Belfast, the district he represented.

Mr. P. F. Kendall remarked that few of the Corresponding Societies during the past year had given any information to the British Association Committee appointed to record the Character and Position of Erratic Blocks, though appeals for help had been made.

The Chairman hoped that the delegates present would note this omission.

In reply to a question from Mr. Eli Sowerbutts Mr. Kendall said that though the Erratic Blocks Committee had been in existence twenty-one years, there were whole counties abounding in erratic blocks from which not a single report had ever been sent. There were thus great gaps in their information which could only be filled by photographs and reports from the quarters which had hitherto not responded to the appeal. Most admirable work had been done in Warwickshire.

Mr. Topley inquired whether any Society had made researches, like those brought before the Conference last year by Mr. Watts, as to the quantity of material brought down streams in flood in the neighbourhood of Rochdale.

Mr. Mark Stirrup thought the work, so far as it had gone, had been brought before the Manchester Geographical Society.

Mr. Symons said that the work had been confined to the Rochdale district. It was desirable that results in other districts should be noted, and all persons wishing to do similar work should consult Mr. Watts at Strines Dale, Oldham.

SECTION D.

Mr. Slater recorded the interesting fact that a member of the Yorkshire Naturalists' Union recently found the wild maidenhair fern on the northern portion of Morecambe Bay. It would not be desirable that the exact spot should be given. He would also remark that it was better to obtain seeds from these rare plants than to take the plant itself.

SECTION E.

Mr. Sowerbutts remarked that their member, Mr. Crook, went before the departmental committee appointed to consider the state of the Ordnance Survey in order to give evidence. He had suggested to Mr. Crook that he should write a report on what had been done by the departmental committee, which might be presented at the next year's meeting of delegates. The examination on Yorkshire mentioned in the report of the Conference of Delegates at Edinburgh did not take place. They would, however, conduct some examinations next year, and he would be glad if the delegates would make their intentions widely known. It was his opinion that there was no cheap book in existence giving a fairly good account of Yorkshire. The examinations were open to all public and private schools. There would be one on Canada for secondary school children. They had been found to know nothing about geography last year, and he looked for some improvement next time.

Mr. Hembry had learned that in a certain county children attending schools were not taught geography in any way. He would like to know if this was the case anywhere else.

Mr. Andrews remarked that, acting on the advice of Mr. Whitaker, he had forwarded a list of thirteen ancient earthworks in Warwickshire to the Ordnance Survey Office, Southampton, ten of which had since been inserted in the map.

Mr. Hembry thought that geography should certainly be a class subject. In secondary schools they absolutely ignored it; but he had been astonished to find that an immense advance had been made in the teaching of geography in primary schools. In many of the latter museums of commercial products were now being formed.

SECTION G.

Professor Merivale had nothing to report about Flameless Explosives.

SECTION H.

Mr. Brabrook made some remarks on the progress made by the Committee appointed to make an Ethnographical Survey of the United Kingdom, whose first report was in the hands of the delegates. The Committee had, he said, obtained, by communication with the Corresponding Societies, a list of nearly 300 villages, with some account of their leading features and peculiarities, all of which were worthy of special examination by the Committee. For this result, which was much beyond their anticipations, the Ethnographical Committee gave their most hearty thanks to the members of the Corresponding Societies who had helped them so efficiently. The next step taken by the Committee had been to draw up a brief code of directions for the guidance of those who had been kind enough to offer assistance. This code would be found at the end of their Report.

Mr. Kenward said that almost all traces of the past had been destroyed in the Birmingham district. They had, however, established a Folklore Sub-committee.

Mr. Brabrook thought that delegation to sub-committees greatly facilitated the work.

Mr. Kenward remarked that in Birmingham they were carefully noting the physical condition of individual children in Board schools, also that of factory hands. Next year they hoped to present a Report on the subject to the Association.

The Chairman said that the Sectional discussions being now ended, he would be glad to hear remarks of any kind that might be of general interest to the delegates.

Dr. Arlidge suggested that a tabular list should be prepared of the Committees of the Association with which it was desired that the Corresponding Societies should co-operate.

Mr. Mark Stirrup said that each year a list of the whole of the British Association Committees was printed and distributed, the names of the members and the objects of the committees being given. He always brought this list before his Society, and asked members to note anything in which they might like to assist.

Mr. T. V. Holmes stated that, when writing in the 'Essex Naturalist' an account of the Edinburgh Conference for the Essex Field Club last autumn, he added to his remarks a list of the ten or eleven Committees in which the Corresponding Societies were specially interested.

NOTTINGHAM, SECOND CONFERENCE, SEPTEMBER 19, 1893.

The Corresponding Societies Committee were represented by Dr. Garson (in the chair), Mr. F. Galton, Mr. Symons, and Mr. T. V. Holmes (Secretary).

The Chairman thought it would be best to take first any discussions upon the committees appointed in the various Sections.

SECTION A.

Mr. Symons said that the work of the Earth-tremors Committee was going on under the care of Mr. Davison, and he did not think that there were other committees connected with Section A that bore upon the work of the delegates. With regard to the Report of the Earth-tremors Committee, he should like to hold it in suspense for a while, in the hope of future co-operation with some of the Corresponding Societies.

Mr. M. H. Mills thought that earth-tremors was one of the subjects in which members of the Federated Institute of Mining Engineers could assist.

Mr. Symons inquired if it would be possible to place instruments underground at a depth of 100 feet.

Mr. Mills did not think there would be any difficulty.

Mr. Mark Stirrup said that some mining engineers thought that it would be useless to place apparatus in mines because of the vibration caused by the workings.

Mr. Symons said that fortunately no difficulty would arise from that cause, as the instruments, though extremely delicate, were not sensitive to vibrations of short period.

Mr. Kenward thought that he knew of a colliery in which instruments could be placed.

SECTION C.

Mr. A. S. Reid said he had been asked by the Sectional Committee to make some remarks. The Underground Waters Committee would present their final Report next year, and would be glad to receive further information up to the date of publication. The Geological Photographs Committee thought that the size of photographs should be left to the donors. As to the best camera further comments from practical photographers were invited; also remarks as to the best methods of printing. With regard to publication, negotiations respecting the proposed album of representative photographs were then in progress. The Erratic Blocks Committee had presented a Report, and they were going to publish as much as they could as soon as possible. The Coast Erosion Committee had not sent in a Report, though they had plenty of material in hand. The Committee on Type Specimens in Museums were making arrangements for the registration of those specimens, and information was required as to where they were housed.

Mr. Tate inquired, with regard to geological photographs, if small photographs taken with a good lens were not preferred.

Mr. Reid replied that the Committee were ready to receive any good photographs.

SECTION D.

Protection of Wild Birds' Eggs.—Mr. Slater thought it was high time something was done to protect the eggs of wild birds. Influence might be brought to bear upon boys. He also deprecated the wanton shooting of gulls.

The Chairman stated that the Committee had been reappointed, and that the delegates would in due time receive a final communication on the question.

Mr. C. H. Torr (Nottingham) said that a valuable suggestion had been made that County Councils, and through them Board schools, should put up notices during the season asking boys not to take eggs. It was of little use to talk of legislation, as the eggs would be gone before it could be obtained.

The Chairman remarked that at Edinburgh much had been said about the number of rare eggs in the possession of collectors.

Mr. Andrews recently visited a small village inn in North Warwickshire, where he saw cases of birds' eggs arranged in the form of crowns. These crowns were sold for £5 each.

Mr. Kenward thought it would be better to appeal to the common-sense and humanity of the collector than to put up notices in Board schools.

Mr. Symons thought an appeal to the common-sense of the people would have a good effect, and that it was useless to trust to legislation. People who made crowns of eggs were irreclaimable.

Mr. Torr said, on behalf of Nottingham, that he would undertake that the matter should be brought before the School Board.

Museums.—Mr. Holmes read a letter from Mr. W. Cole, Hon. Sec. Essex Field Club, on the maintenance of local museums. Mr. Cole thought that if an annual sum for the maintenance of local museums could be obtained from the Technical Education Grants in each county there would be no great difficulty in obtaining substantial sums towards buildings and fittings. The fear that a museum might not be permanent often kept back subscriptions. Donations, both of money and of specimens, would rapidly come in when once the public felt that the museum would be permanent; and in no way could a portion of the Technical Education Grant be better expended than in placing on a satisfactory footing the local museum of the county.

Mr. Symons thought the idea of getting a grant from the source suggested a very good one.

The Chairman hoped that members of the Corresponding Societies would occasionally read papers on the specimens in their local museums, each writer keeping to a certain department. These papers, if published, would be catalogued in the Association's list, and brought before the notice of many workers in the same subject elsewhere. They would also be available for reference at headquarters in London.

Mr. Stirrup believed that something had been done in that way. A Museums Association had been started, and had met that year in London. In the report from the Owens College Museum there was a paper dealing with the subject of type specimens.

The Chairman thought that the object of the Museums Association was rather to discuss the best kinds of general arrangement than to describe the contents of museums.

Mr. Stirrup and Mr. Tate both expressed an opinion that descriptions of type specimens would be very valuable.

SECTION H.

The Chairman said that, as representative of Section H, he had to draw the attention of the delegates and the Corresponding Societies to the—

Ethnographical Survey of the United Kingdom.—The first Report of the Committee had been placed in the hands of the delegates at their first conference, and he hoped they would bring it before their respective Societies, as the kind of work required is essentially local and such as would give great scope for investigation to the members of their Societies. It includes observations on (1) the physical types of the inhabitants, to be ascertained by photographing and recording the characters and measurements of the people; (2) folklore; (3) peculiarities of dialect; (4) monuments and other remains of ancient culture; (5) historical evidence as to continuity of race. The Report contains minute directions as to how the investigations are to be made.

Exploration of Ancient Remains.—The Committee of Section H had passed the following resolution, to which they desired the attention of the Corresponding Societies to be drawn:—'That in the opinion of this Section it is desirable that the attention of archæologists and others be particularly called to the great importance of preserving with the utmost care all human remains found in ancient dwellings, graves, tumuli, and other burial places. It is equally as important to preserve the limb-bones and pelvis as the skull. The information yielded by human and animal remains is equally as important as that derived from pottery, implements, coins, &c. When any difficulty occurs in obtaining competent aid in examining such remains, explorers are requested to communicate with the Secretary, Anthropological Institute, 3 Hanover Square, London, W.' He said that it was much better not to attempt to excavate barrows, &c., unless it was done thoroughly.

After some remarks on a proposed excursion of the delegates a vote of thanks to the Chairman closed the proceedings.

The Corresponding Societies Committee, in accordance with the announcement made to the General Committee, present the following Report of the Oxford Conference:—

The Council nominated Professor R. Meldola Chairman, Mr. Cuthbert E. Peek Vice-Chairman, and Mr. T. V. Holmes Secretary to the Conference. These nominations were confirmed at the meeting of the General Committee held at Oxford on Wednesday, August 8.

The meetings of the Conference of Delegates of the Corresponding Societies were held on Thursday, August 9, and on Tuesday, August 14, in the New Examination Schools, at 3.30 P.M. The following Corresponding Societies nominated delegates to represent them at the Oxford meeting:—

Bath Natural History and Antiquarian Field Club.	Rev. H. H. Winwood, M.A., F.G.S.
Belfast Naturalists' Field Club . .	W. Gray, M.R.I.A.
Berwickshire Naturalists' Club . .	G. P. Hughes.
Birmingham Natural History and Philosophical Society.	J. Kenward, F.S.A.
Bristol Naturalists' Society . . .	Dr. A. Richardson.
Burton-on-Trent Natural History and Archæological Society.	James G. Wells.
Cardiff Naturalists' Society . . .	E. Seward, F.R.I.B.A.
Chesterfield and Midland Counties Institution of Engineers.	M. H. Mills, F.G.S.
Cornwall, Royal Geological Society of .	Howard Fox, F.G.S.
Croydon Microscopical and Natural History Club.	Thos. Cushing, F.R.A.S.
Dorset Natural History and Antiquarian Field Club.	Rev. O. P. Cambridge, M.A., F.R.S.
East Kent Natural History Society. .	A. S. Reid, M.A., F.G.S.
East of Scotland Union of Naturalists' Societies.	Robert Brown, R.N.
Essex Field Club	T. V. Holmes, F.G.S.

Federated Institution of Mining Engineers.	M. H. Mills, M.Inst.C.E.
Glasgow Archæological Society	J. B. Murdoch.
Glasgow Geological Society	
Glasgow Philosophical Society	Prof. J. G. McKendrick, M.D., F.R.S.
Hampshire Field Club	T. W. Shore, F.G.S.
Hertfordshire Natural History Society and Field Club.	John Hopkinson, F.L.S., F.G.S.
Isle of Man Natural History and Antiquarian Society.	His Honour Deemster Gill.
Leeds Geological Association	B. Holgate, F.G.S.
Leeds Naturalists' Club and Scientific Association.	Harold Wager, F.L.S.
Liverpool Geological Society	O. W. Jeffs.
Malton Field Naturalists' and Scientific Society.	R. T. G. Abbott.
Manchester Geographical Society	Eli Sowerbutts, F.R.G.S.
Manchester Geological Society	Mark Stirrup, F.G.S.
Midland Union of Natural History Societies.	W. E. Collinge.
Norfolk and Norwich Naturalists' Society	Clement Reid, F.G.S.
North of England Institute of Mining Engineers.	Prof. J. H. Merivale, M.A.
Northamptonshire Natural History Society and Field Club.	C. A. Markham, F.R.Met.Soc.
North Staffordshire Naturalists' Field Club.	Dr. J. T. Arlidge, M.A.
Nottingham Naturalists' Society	W. Bradshaw.
Perthshire Society of Natural Science	H. Coates, F.R.S.E.
Rochdale Literary and Scientific Society	J. Reginald Ashworth, B.Sc.
Somersetshire Archæological and Natural History Society.	F. T. Elworthy.
South London Microscopical and Natural History Society.	F. W. Hembry, F.R.M.S.
Tyneside Geographical Society	G. E. T. Smithson.
Warwickshire Naturalists' and Archæologists' Field Club.	W. Andrews, F.G.S.
Woolhope Naturalists' Field Club	Rev. J. O. Bevan, M.A.
Yorkshire Geological and Polytechnic Society.	Thos. Tate, F.G.S.
Yorkshire Naturalists' Union	M. B. Slater, F.L.S.

OXFORD, FIRST CONFERENCE, AUGUST 9, 1894.

The Corresponding Societies Committee were represented by Professor R. Meldola (Chairman), Professor T. G. Bonney, Sir John Evans, Sir Douglas Galton, Dr. Garson, Mr. J. Hopkinson, Mr. Cuthbert Peek, Sir Rawson Rawson, Mr. G. J. Symons, Mr. W. Topley, Mr. W. Whitaker, and Mr. T. V. Holmes (Secretary).

The Chairman remarked that as this was their tenth Conference it had been suggested to him that it would afford a good opportunity for a review of the work done during that period. On the whole, however, he thought that a review of that kind might form a dangerous precedent, as tending to the delivery of an annual address which would occupy time more profitably spent in discussing topics in which the delegates were specially interested. Hitherto, owing to a bye-law enacting that the Report of the Corresponding Societies Committee should be presented to the

General Committee of the British Association, the Reports of these Conferences had always been a year behind; that held at Edinburgh in 1892, for example, appearing in the British Association volume giving an account of the proceedings at Nottingham in 1893. Steps had been taken, however, to prevent this delay in future, and in the Oxford Report of the British Association the account of the Nottingham Conference and that of the Oxford Conference would appear together. In order that there should be no want of material for discussion at these Conferences, their Secretary and he had written to the Recorder of each Section asking him to bring the existence of the Conference of Delegates under the notice of investigators in those departments of science of which the work might be aided by the co-operation of local observers. They had also taken a new departure in announcing beforehand that some special subject would be discussed at the Conference. On this occasion they had been fortunate enough to secure the attendance of Mr. Cuthbert Peek to open a discussion on Local Museums.

Mr. Cuthbert Peek, after stating that he was under great obligations to that admirable organisation, the Museums Association, said that he proposed to deal with the subject under the following headings:—

1. Methods of registration and cataloguing.
2. The protection of specimens from injury and dust.
3. The circulation of specimens and type-collections for educational purposes.
4. Central referees for nomenclature and classification.
5. The most satisfactory methods of making museums attractive.
6. Museum lectures and demonstrations.
7. The relations between museums and County Councils.

1. *Methods of Registration and Cataloguing.*—Having examined several systems before arranging a small general museum of his own, he had come to the conclusion that for small museums the card catalogue was the most convenient on account of the ease with which changes and additions could be made. Sectional letters distinguished the various classes of objects. Each specimen when received had a number allotted to it under the letter assigned to the Section. In order that the number might remain attached to the specimen, he painted the letter and number on the specimen with red or white paint, and gave them when dry a coat of oil varnish. When practicable it was a good thing to paste a photograph showing the locality at which the object was found at the back of the card. Labels were often displaced by the careless cleaner, but if the exact dimensions of a specimen, with a rough outline of it, were entered on the back of a card, identification would always be possible.

2. *The Protection of Specimens from Injury and Dust.*—On this subject it was necessary to remind them that every closed case was practically acted upon by changes in the pressure of the atmosphere (in the same way as the cistern of a mercurial barometer), and that it drew in or gave out air and dust with every change of pressure. Professor Miall, at the Yorkshire College, had a rectangular hole cut in the top of each case and covered with damiette. This filters the air passing in. He (Mr. Peek) felt inclined to use a tube filled with cotton-wool for this purpose. It must be remembered that enough air should be admitted at the authorised entrance to prevent supplies from being sucked in through the inevitable joints and cracks elsewhere.

3. *The Circulation of Specimens and Type-collections for Educational Purposes.*—The importance of educating the eye was now generally recognised and the London scientific societies are more and more introducing the optical lantern at their evening meetings. The advantage of the circulation of loan collections illustrating the subjects taught in elementary schools was therefore obvious. At Liverpool a system had been elaborated by which loan collections were prepared and circulated among a large number of schools. Experience had shown that the collections should be arranged in cabinets, each containing some special class of objects, such as food products, woods, &c. Those wishing to organise a plan for the circulation of collections of this kind should consult a Paper by Mr. J. Chard in the Report of the Museums Association for 1890.

The educational advantages of a museum were much increased by a liberal use of pictorial illustrations placed as near as possible to the objects illustrated. In the case of minute objects drawings on a larger scale were of the highest value, while models and casts were often of the utmost service. Labels should be clear, and should indicate the most important points in plain language. When specimens could be replaced without difficulty a certain amount of handling might be permitted. It was most desirable that overcrowding should be avoided, and that the utmost care should be taken in the selection of type-specimens. Much economy of space would result from the adoption of an American invention which he would briefly describe. The side of the cabinet, instead of having one slide for each drawer, has a series of slides, one inch apart, all the way up the side, the bottom of each drawer having a tongue to fit into one of these slides. It was clear from this that the drawers might be made in multiples of an inch and arranged in any order desired.

4. *Central Referees for Nomenclature and Classification.*—One of the greatest difficulties which the average curator of a small museum had to deal with was the nomenclature of the varied specimens under his charge. An organisation of specialists who would for a small fee allow specimens to be forwarded to them for identification would be of the greatest possible value. Certain abstruse questions might not even then be easy to answer; but if nine-tenths of our museum specimens could be accurately catalogued a great step in the right direction would be taken.

5. *The most satisfactory Method of making Museums attractive.*—To those who know the museums at South Kensington, or some of the equally well-arranged local museums, this heading might seem unnecessary. But many present might be able to call to mind some collection in a country town containing many most valuable local specimens, the very existence of which was unknown to the majority of the inhabitants. This state of things was yearly becoming rarer; but many persons could point out some museum almost as much fossilised as the fossils it contained, with labels either illegible from age or invisible from displacement. Those who casually entered such museums seldom revisited them. It was most desirable that the English as well as the Latin name of a specimen should be given. Much might be done to allow of comparisons between creatures of different families or genera. Thus, at the Natural History Museum, South Kensington, the skeletons of a man and of a horse in the attitude of running had recently been placed the one in front of the other, so that the relations of the two, bone for bone, could be distinctly seen. The surgical, ordinary, and veterinary names of the bones were added throughout

6. *Museum Lectures and Demonstrations.*—While the great value of case-to-case explanations was invariably admitted, the difficulty attending any attempt to make a museum demonstration useful to any large number of persons was equally obvious. One most experienced demonstrator had stated that the largest number that can receive real benefit from a case-to-case demonstration is about a dozen, and had recommended that the lecture, illustrated by specimens and lantern slides, should be given in an ordinary lecture-room, and a demonstration afterwards in the museum to the smaller number seeking further information. In any case it was most desirable that the demonstrator should be placed on a temporary stand, so that he might see and be seen by his audience.

7. *The Relations between Museums and County Councils.*—It having always appeared to him that demonstrations in museums should take a very prominent part in technical education, especially in rural districts, he had been surprised that so little assistance had been given in aid of local collections by County Councils. In order to ascertain what had been done in that direction he had sent out a circular to county council technical education committees, and found that local museums and free libraries had been assisted only in nine cases. The County Council of Cumberland had been the most liberal, having made a grant of 600*l.* per annum during the last three years for the purpose of aiding the Corporation of Carlisle to erect a museum, free library, and art school. A grant had also been made to a free library at Whitehaven for the purchase of text-books for the use of students at technical instruction classes, and a grant of 200*l.* per annum had been given to the local board of Millom in aid of the free library and technical school at that town. In Westmorland a grant of 100*l.* had been made to the Kendal Free Library, and a similar sum had been given for the purchase of books on scientific subjects at other centres in the county. In Northumberland 50 per cent. of the cost of technical books for village and other libraries had (under certain conditions) been defrayed. At Leeds grants had been made to the Free Public Library Committee of the Corporation for the purchase of pictures and books. In Hertfordshire money had been given to free libraries for the purchase of technical books, and in Montgomery grants had been made in two cases. In Surrey no aid had been given to free libraries, but it was proposed to found a museum in connection with buildings for technical education and a reference library. The London County Council had a proposal to aid a certain museum under consideration; and in Dorsetshire the museums at Poole, Dorchester, and Sherborne had all received aid. From some counties no information had yet been received, but enough had been stated to show that there was no insuperable obstacle to the application of money intended for technical education to the development of museums. A leading object with the Government was the development of local activity, and he felt convinced that any grants made to local museums and free libraries would tend more than anything else to further that object.

In conclusion Mr. Peek drew attention to the magnificent museum founded at Oxford by General Pitt-Rivers, the arrangement of which was unique.

The Chairman thought they were much indebted to Mr. Peek for his paper, and invited remarks thereon.

Sir John Evans said that Mr. Peek had left little for anyone to add. The card catalogue would commend itself to everyone on account of the facility with which it could be consulted, but it was a question whether the American system of having a perforated card through which a wire passed, so that the card could not be disturbed, was not preferable. The suggestion that a slight sketch of the object should be made on the back of the card was a valuable one. In the British Museum the date at which an object was received was generally painted upon it. He would be glad if anyone could suggest any means by which the ordinary cabinet could be kept free from dust. It exhaled air when the day was warm, and inhaled it in the cooler evening. He had tried a lining of cotton-wool, but did not think the result was perfectly satisfactory. He thought a cabinet constructed on the American principle, alluded to by Mr. Peek, would be liable to dust unless its door was extremely close-fitting, but he had applied the principle in a somewhat different manner. As regards referees for nomenclature and classification, an association like that suggested would, no doubt, be useful but at the present time any curator might consult the keepers of the various departments of the British Museum, either at South Kensington or at Bloomsbury, with a certainty of prompt and valuable assistance. He doubted whether grants to museums would be permitted to pass by the Government auditors, though a grant of technical books to a local museum might be allowed. In thanking Mr. Peek for the manner in which he had brought this subject before them, he was sure that he gave utterance to the feeling of all present.

The Rev. O. P. Cambridge believed that in some cases County Councils had made grants which they were not altogether legally entitled to make, but which, from the good work done, were not likely to be called in question. As regards the obliteration of labels, he had a large collection of specimens in spirits of wine, and had been in the habit of gumming labels on the outside. In the course of years he had found that these labels soon became spotted and indistinct, and had consequently written new labels on good paper with a pencil and placed them inside the glass jars with the most satisfactory results.

Sir Rawson Rawson, whose experience had been partly tropical, had not always found pencil marks indelible.

The Rev. O. P. Cambridge wished to add that some care was necessary in selecting a pencil, which should neither be very hard nor very soft.

Dr. Garson could corroborate what had been said as to the advantages of using pencils in spirit preparations. No kind of ink would answer, but a pencil mark would remain a very long time after immersion in spirit. It was an advantage to use a rough paper.

Mr. W. Gray thought they were all much indebted to Mr. Peek for the admirable way in which he had handled the subject. It was first necessary to stir up an interest in a locality in order to get a museum; secondly, to have the specimens properly housed; and thirdly, to make the museum attractive. To be attractive it must be educational, and arrangements should be made for the circulation of some of the cases through the country. Aid may then be fairly demanded from the County or City Council. The circulation of specimens did away with the dull, dusty monotony so characteristic of some museums, and which usually prevented them from being visited more than once or twice. Variation in the aspect of a museum constituted a most important element of attraction. In Belfast, through the agency of the Society he represented, they had established the Belfast Central Museum, Art Gallery, and Library. Sir John Evans had given the museum three or four thousand valuable specimens. But they were still wanting in a proper organisation of their local museum for educational purposes, and the sentiments expressed at that meeting would enable him to urge the matter with additional emphasis before the Town Council.

Mr. T. W. Shore stated that three years ago he had moved a resolution, at the Cambridge meeting of the Museums Association, pledging the Association to do what it could to obtain aid for museums from County Councils. He hoped that the gathering before him might be able to aid the movement in some way. Mr. Peek had mentioned that the clerks of many County Councils expressed doubts as to the legality of grants to museums, but Mr. Cambridge had shown how the difficulty might be overcome. It was clear that grants could be made by County Councils to defray the expense of lectures and demonstrations in museums. He would therefore suggest that circulars might be sent to County Councils pointing out that, in the opinion of that meeting, grants in aid of lectures and demonstrations in museums might be made with excellent educational results and without any risk of going beyond the law.

Mr. Sowerbutts remarked that, though County Councils might be subject to the Government Auditor, County Boroughs were (he thought) not so controlled. In Lancashire they did not trouble the auditors, but when the councillors became extravagant they turned them out at the next election.

Mr. Kenward said that in Birmingham the Corporation had established an excellent museum and an art gallery which were entirely supported by the rates. They had never sought aid from the County Council.

Mr. T. V. Holmes had in his hands a letter from Mr. William Cole, Secretary to the Essex Field Club, who was intimately acquainted with the system of technical education as it was carried out in Essex. Mr. Cole lamented that nothing had been granted by the County Council to aid museums, but thought that to do so was probably beyond their legal powers, and hoped for an amendment of the Act. He would doubtless be cheered by Mr. Peek's observations on that point, which showed that grants to museums were by no means unquestionably illegal—to say the least. Mr. Cole's experience had given him a very low notion of the efficiency of mere lecturing, especially in rural districts. Of course a lecturer usually brought specimens with him, but with the departure of the lecturer the specimens also departed, and scarcely any real interest in the subject was aroused. What was really wanted was a permanent central museum which was continually sending forth loan collections to the remoter districts, and which allowed them to remain there for a certain time after the lectures, illustrated by these collections, had been given. Mr. Cole, however, did not think that museums should be entirely worked by County Councils, as that would greatly weaken the interest taken in museums by the naturalists and field clubs who had usually originated them. But the funds of almost all societies of naturalists were so small that the greatest hindrance to the development of a museum was a want of money, which suggested a want of permanence. By a small grant towards the expense of a curator, or for some similar purpose, obtainable only while the museum remained efficient, a County Council might do very much to render a museum permanent and efficient without diminishing the interest of individual naturalists in its development.

Dr. Brett said that, in order to bring the matter to a practical conclusion, he would like to propose that their Secretary should write to all the County Councils in Great Britain, urging upon them the importance of giving aid to their own local museums.

After some discussion, in which Dr. Brett, Sir Douglas Galton, Mr. Gray, Sir John Evans, Mr. Cushing, and Mr. Whitaker took part, the following resolution was proposed by Sir Douglas Galton, who remarked that in his county it was held to be contrary to the law for a County Council to give directly to a museum :

'That in the opinion of this Conference it is desirable that local natural history societies, and those in charge of local museums should place themselves in communication with the technical instruction committee of the county or borough in which they are placed with the view of obtaining pecuniary grants towards extending technical knowledge by means of lectures or by demonstrations in museums.'

Dr. Brett seconded the resolution.

Mr. Coates stated that at Perth they were building a large addition to their museum, and had applied for aid both from the Town Council and the County Council. They had obtained a grant from the County Council on the condition that they should provide specimens suitable for agricultural teaching. These specimens would be used for lectures and demonstrations. They had been advised that they could not otherwise obtain the grant.

Mr. Elworthy said that a difficulty under which many of them laboured had not yet been touched upon. They needed the services of an expert who would visit a museum, and, for a certain fee, pronounce with authority 'this is rubbish' in the case of worthless specimens. A Secretary who would not venture to get rid of rubbish on his own responsibility would do so at once if backed by the opinion of a disinterested expert.

Sir John Evans thought that the opinion of the Secretary ought to be deemed sufficient. In answer to a suggestion that the word 'specimens' should be added to 'lectures and demonstrations' in the resolution, he remarked that County Council money could not be spent in acquiring specimens.

The Chairman then put the resolution to the meeting, and it was unanimously adopted. He then asked if any delegates had other points connected with museums to bring forward.

Mr. Seward, as representing the County Borough Council of Cardiff, was most anxious to learn, if possible, what things bought for a museum with the view of making it more attractive and useful to the poorer classes could be legally purchased under the Act.

Sir John Evans replied that it seemed to him that the last resource in these cases was the Science and Art Department at South Kensington. If the Borough Committee wished to purchase specimens to illustrate lectures for the advancement of technical education, the Clerk of the Council should write to South Kensington to inquire as to the legality of the proposed grant. If the specimens were required simply to increase the efficiency of the lectures, they would probably be regarded as part of the lecture apparatus, and the vote sanctioned.

Mr. Gray remarked that at Belfast they always got assistance from South Kensington in acquiring proper specimens for the museum.

The Chairman thought that the Conference could not possibly attempt to decide the point raised by Mr. Seward. He felt sure that they were all most grateful to Mr. Peek for having introduced this discussion on museums, which he believed would lead to most useful results.

SECOND CONFERENCE, AUGUST 14, 1894.

The Corresponding Societies Committee were represented by Professor R. Meldola (Chairman), Dr. Garson, Mr. Hopkinson, Sir Rawson Rawson, Mr. Symons, Rev. Canon Tristram, Mr. Whitaker, and Mr. T. V. Holmes (Secretary).

The Chairman said that with reference to the discussion at the last Conference, he hoped that those delegates who were situated in places where there were local museums would do their best to further the resolution then passed, and report progress at the Conference next year. They had now to consider work done in connection with the various Sections, beginning with Section A.

SECTION A.

Meteorological Photography.—Mr. Clayden remarked that two years ago he had asked to be put into communication with gentlemen willing to photograph clouds and other meteorological phenomena. He had been put into communication with photographers, but the number of photographs sent had been very small. Nevertheless, an almost sufficient collection had been received. He would, however, be grateful for photographs of lightning showing anything abnormal. Now and then he read of the remarkable results of a whirlwind in some district, when it was too late for him to take steps to have the effects photographed. But if, in such cases, the secretary of a local society would get photographs taken at once, and send them to him, such records would be most valuable.

Sir Rawson Rawson inquired if Mr. Clayden had the photographs of storms and lightning recently exhibited at the Royal Society, and Mr. Clayden replied that he thought he had a considerable number of them.

Mr. Holgate thought that if Mr. Clayden wrote to the secretary of a local society, the latter would always be able to obtain information as to the existence of photographs showing the results of a whirlwind or other abnormal occurrence. Mr. Clayden replied that he had often tried that plan, but had usually found that the damage had been cleared away, and that he was too late. It was therefore desirable that the secretaries of the local societies should arrange for photographs.

Mr. Hembry inquired whether Mr. Clayden had received photographs showing the results of a thunderstorm a few weeks ago in which a church had been struck and two men killed. Mr. Clayden replied that he had not.

Mr. Symons remarked that much help could be given by local societies if they would send in reports promptly. The difficulty was that individual members did not feel personally responsible in the matter. Everybody's business was nobody's business.

Remarks on the advantages to be derived from, and the means of securing increased co-operation between British Association committees and local societies were made by Mr. Kenward, Mr. Gray, and Mr. Symons.

Earth Tremors.—Mr. Davison said that in the last Report of the Earth-tremors Committee there was a description of a bifilar pendulum invented by Mr. Horace Darwin. It had been tried for a year at Birmingham, and in consequence of experiments made there a new form of instrument now exhibited was being constructed. Its cost would be about

60*l.* The local societies were so distributed over the country that most places where it was desirable that one of these instruments should be placed were within the area of one of them. Instruments placed on the course of great lines of fault (or dislocation of the strata) would yield results of much value.

Mr. Horace Darwin exhibited and explained the construction and use of the bifilar pendulum. He said it was not affected by the rapid, complicated movements which took place during an earthquake, or by the slight tremors caused by passing carts or trains. The movements which it would measure were such as would make a factory chimney or a vertical post fixed in the ground lean over to one side. Extremely small movements of this kind could be measured and recorded on photographically prepared paper. A full account of the instrument was given in 'Nature,' July 12. It is made by the Cambridge Scientific Instrument Company.

Mr. Symons, as Chairman of the Earth-tremors Committee, explained how the work of the Committee had grown and in what direction they needed additional help. In the first place, the attention of the Committee had been directed to a solution of the question why certain vibrations were recorded by an instrument which had been placed at the bottom of one of the deep coal-mines of the district of Newcastle-on-Tyne. Instead of a straight line a series of pulsations had been obtained. They were traced to two causes—one the gradual settlement of the ground in consequence of the removal of the coal, the other the beating of the waves on the coast. They had since been looking for traces of earthquake tremors. Mr. Davison, on one occasion, watched his instrument for some time, as he found pulsations were taking place. These pulsations eventually turned out to have been produced by the earthquake then going on in Greece. They wanted information as to the changes going on in connection with the faults in geological strata, and, if possible, to get records of the alterations in the earth's crust caused by tidal waves. When the ocean was piled up at one part of the earth's surface it was quite possible that the elastic surface of the earth bent slightly under it. Observations of that kind should be made at more than one station. The work was now going on at Birmingham under Mr. Davison, but they hoped that the Association would give them a grant for a second instrument. They wished to make sure that they were recording, not merely local phenomena, but the great general phenomena of the earth's crust. He was glad to be able to record that one instrument had been established at an observatory south of Biarritz by M. Antoine d'Abbadie, who had kindly presented a duplicate instrument to the new observatory at Edinburgh. They were anxious to see two or three instruments of this kind established in different parts of the British Isles, and hoped that some of the wealthy friends of the societies represented at that Conference might co-operate in finding the money for the instruments.

Mr. Tiddeman asked whether the instrument could be placed in an ordinary house, or whether it required a special place in a separate building.

Mr. Symons replied that Mr. Davison had placed it on the cellar floor. A separate building might be preferable, but was more expensive.

Mr. Mills did not think the instrument would be of much use to persons without a special knowledge of it.

Mr. Symons remarked that Mr. Darwin had undertaken to give all the necessary information, and so had Mr. Davison.

In answer to a question from Mr. Mills, he added that it was not essential that an instrument should be placed in a mining district, but it was desirable that they should be scattered throughout the country.

Mr. Seward said that he would try to get one placed in one of the deep mines of South Wales.

The Chairman hoped that by next year some of the Corresponding Societies would have something to report on this question. Mr. Darwin had kindly offered to explain, after the termination of the Conference, the mechanical details to any persons interested.

SECTION B.

Pollution of Air in Towns.—Dr. G. H. Bailey said that for three or four years they had been engaged in Manchester, in connection with the Manchester Field Naturalists, in examining the air of towns with the view of ascertaining the extent to which it was polluted. This was a question of much practical importance, for the amount of the pollution was a pretty good indication of the death rate. Those times of the year at which the air was most polluted were those at which the death-rate was highest. Hitherto there had been very little attempt to ascertain the nature and degree of the pollution, and it had been their endeavour to examine the methods by which the pollution of town air could be detected, and to determine its nature and amount. They had almost perfected a method for determining the amount of sulphur compounds in the air, and one for measuring the amount of sunlight in towns. They had found that, whilst in extreme cases of pollution carbonic acid gas varied between four and seven parts in 10,000, the sulphur compounds varied from less than one up to fifty per million parts. The pollution varied practically as did the amount of the sulphur compounds. The work was hardly yet in so complete a state that he could recommend its adoption at a large number of other towns, but it would interest the delegates to know what had been done. They were at that time working at a method for determining the nature and amount of the pollution of different districts of large towns. The work already done had been chronicled in the 'Journal of the Manchester Field Naturalists' for 1893. They had come to the conclusion that about 50 per cent. of the daylight was cut off by the smoke of a town, speaking of that form of light which could be registered, viz., the actinic rays. They had found that the centres of large towns sometimes showed a diminution, as compared with the suburbs, of about 50 per cent., the diminution of light in the centres of large towns as compared with the open country amounting to about 75 per cent. When their methods were more fully perfected they hoped to have the co-operation of members in more rural districts. They had been working at the indoor as well as the outdoor pollution of the air.

Mr. Slater remarked that the plants of very smoky districts were either destroyed or injuriously affected by the smoke.

The Chairman said that it was well known to London naturalists that lichens were once common on tree trunks in Epping Forest, but few if any were to be found there now. It is too near London for them to flourish.

Mr. Symons remarked that Dr. Bailey had apparently employed the photographic process for measuring the amount of sunlight, as he spoke of the actinic rays. He (Mr. Symons) would point out that the burning sunshine recorders showed exactly the same result for the other end of the spectrum.

The Chairman thought the matter one of the greatest importance to all dwellers in large towns, and Sir Rawson Rawson remarked on its special interest to medical men.

Mr. Holgate inquired whether they were to understand that the proportion of sulphur in the air of a town was an indication of the amount of its death-rate.

Dr. Bailey said that he had been driven to the conclusion that the amount of the death-rate of a district was closely connected with the amount of pollution in its air. While they had in Manchester, in ordinary weather, a death-rate from respiratory diseases of four or five per thousand, in foggy weather, when the air was most polluted, there was a mortality of twenty or more per thousand from diseases of that class. Plants suffered even more than human beings from air pollution. That part of the work had been undertaken by Prof. Oliver, of University College, London, who had already published a long account of the work he had done in connection with the Royal Horticultural Society. Dr. Bailey added that the method he had used for recording sunlight was not photographic, but was that originally suggested by Mr. Angus Smith. It gave a relative not an absolute record, and recorded the amount not only of sunlight but of daylight. Delegates would find a full account of the methods employed in the 'Journal of the Manchester Field Naturalists' for 1893.

SECTION C.

Mr. Whitaker (representing Section C) said that the first subject to which he would refer was 'Coast Erosion.' The final report on this subject was to have been made this year, but it would, he hoped, be made next year. After the publication of the Report the subject would be handed over to the Corresponding Societies, and those which have coast borders could continue the work by recording changes on 6-inch maps, or, still better, on 25-inch maps. The other subject was the 'Circulation of Underground Waters.' The committee dealing with this matter should have ceased to exist this year, but the final report would not appear till next year. In this case also the local societies would be able to continue the investigation. He took the opportunity of telling the representatives of the Corresponding Societies that they wanted records of wells and borings, the nature of the beds passed through, and the exact site; also the water-levels and the effects of pumping on them, the temperature, an analysis of the water, and any other useful information. It was suggested that the twenty reports of the Committee should be published, but in that case the information about any particular district would be scattered through several of these reports. But the Committee thought that if these reports were arranged topographically, and possibly condensed, many local societies would be glad to possess the volume. He hoped the local societies would be able to encourage the Committee in the publication of the work by subscribing for a copy of it. It would probably form a book of 250 to 300 pages, and the cost would not exceed 10*s*.

Mr. Slater said that water had been obtained from a deep well at Malton but the Local Government Board had objected to its quality.

They were trying to adopt the remedies suggested, and when a report was issued he would hand it to Mr. Whitaker.

Mr. Holgate remarked that in the neighbourhood of Leeds they had Coal-Measures, and had found a different kind of water at each level. This was the case throughout the coal-basin.

Erratic Blocks.—Mr. Murdoch said that it seemed a pity that the labours of the Erratic Blocks Committee were confined to England and Ireland. The work in Scotland had been by no means so completely done as was commonly supposed.

Mr. Gray said that in Ireland they had issued their first report on erratic blocks.

Professor Blake wished to inform the representatives of the local societies that, being engaged in examining the microzoa of clays, particularly of Jurassic clays, he would be much obliged if they could send him samples of fossiliferous clays from various parts of the country. He would be glad to report to the sender on the general character of these clays and their microzoa. There was another matter he should like to take the opportunity of mentioning to them. For the past three years he had published a book ('Annals of British Geology') which contained abstracts of the geological papers read before the local as well as the London societies. It had not hitherto been self-supporting, though the loss was decreasing. He had failed to get a grant from the British Association, and could no longer afford to publish at a loss, so, though the manuscript for the fourth volume was ready, he could not publish it unless he received additional promises of support. As this state of things was, in all probability, unknown to most of the local societies and their representatives, he had taken this opportunity of mentioning it. Mr. Whitaker trusted Mr. Blake's remarks would cause an increased sale to that most useful work, the 'Annals of British Geology.'

Geological Photographs.—Mr. Jeffs stated that they had received 1,055 photographs. Some districts were totally unrepresented, possibly from want of photographers. The Geological Photographs Committee had passed a resolution recommending the Council of the British Association, whose property the collection was, to deposit it in the Museum of Practical Geology, Jermyn Street, London. As to the question of publication, they had not yet found a publisher who would take the matter up.

The Rev. H. H. Winwood had found great difficulty in getting an amateur to photograph geological sections. Professional men were sometimes worse.

SECTION E.

Mr. Sowerbutts remarked that last year he had promised to give a report of the examination in geography at the primary schools of Cheshire, Lancashire, and Yorkshire. Every delegate had received a copy of that report. They had come to the conclusion that geography would never be taught satisfactorily unless it was made a compulsory subject. It was disgraceful that geography was so badly taught, or utterly neglected, in the schools of a country which had territory in every part of the world. They had been pleased, however, to notice that much progress had been made in some of the primary schools by the institution of school museums. It was a singular fact that

Yorkshire the girls won all the prizes, and in Lancashire the boys. The council of the Manchester Geographical Society thought that next time they would test the secondary schools. His society had, for the last two or three years, published an analysis of the chief geographical papers which had been published in English and foreign journals, a necessary though expensive work. He hoped that some day there would be an international committee to deal with that matter. The report on the Ordnance Survey was a very interesting and important one, and he hoped the delegates would read it.

Mr. Whitaker said that the report referred to had not reached members of the Corresponding Societies Committee, and Mr. Sowerbutts regretted having forgotten them.

SECTION H.

Ethnographical Survey.—Mr. Brabrook remarked that the delegates had shown so much interest in this question, and so many had given assistance, that he need only give some account of the progress made since their last Conference. During the past year they had their list of suitable villages considerably increased: there were now 367, a much larger number than they had expected would be suggested as places suitable for examination. It had taken much time to draw up the forms of schedule, of which each delegate had received a copy, but he thought the work well worth doing. He might mention that at Ipswich, where they would meet next year, a sub-committee had been formed to assist them, which had already been of much use; while at Liverpool, where they would meet in 1896, the keeper of the museum, Dr. Forbes, had been kind enough to undertake that his assistant in the ethnographical department should set to work on the lines we propose to adopt. Many gentlemen engaged in special observations at particular places might obtain much assistance from the additional facts which had been collected by Dr. Forbes. In Wales their sub-committee had met, and had formulated some proposed regulations for action which the Central Committee thought very wise, and they hoped that work would soon be begun in Wales on the lines indicated by Mr. Allen. In Ireland Professor Haddon had drawn up a report of the work done there, which was of great importance. In combination with Dr. C. R. Brown he had prepared a great number of papers resembling the schedules of instructions issued by the Central Committee. He hoped that his Honour Deemster Gill would become interested in the matter, because they had two excellent correspondents in the Isle of Man already—Mr. Moore and Mr. Kermode—and it appeared to him that those three gentlemen would form an admirable sub-committee for that quarter. In Scotland they had a promise of assistance from gentlemen representing the Glasgow Archæological Society. He had lately presided at a congress of archæological societies, and had made a statement on the subject of the Ethnographical Survey. The organisers of the congress were good enough to ask him as to the cost of an explanatory statement which could be circulated among their own members with their transactions. He had answered that he would be willing to pay for the setting-up of the statement, if the various societies would pay the cost of printing off the number of copies required. He would be pleased to make a similar arrangement with any of the corresponding societies, and would be glad to receive suggestions of any kind m any of the delegates present. He wished to make one additional remark. They had been told that their instructions with regard to photographing were too minute. But those instructions had been drawn up by Mr. Francis Galton with reference to his system of composite photographs, and any departure from them would make the application of that system comparatively difficult. At the same time they did not wish to lose any photographs which might come in useful, even if, in their case, the instructions had not been followed.

Mr. Sowerbutts stated that with regard to photographs the old people in his district objected to be photographed and measured, apparently from a notion that to allow it would be to render themselves subject to witchcraft. They had found a difficulty in providing the necessary apparatus for their ethnographical work.

Dr. Garson wished to say that as regards the photographs it was not necessary to get all the appliances Mr. Galton had mentioned. A very simple arrangement could be made by means of three sticks set up so as to give the exact notion of a person's height, the top of his head coming across the transverse stick. The seat could be raised or lowered like that of a piano-stool, so that each person sitting on it would have his head in the same place, whatever his height might be. It was well also to have chalk lines on the floor at right angles to each other, the sitter being directed to look along one or the other of them. They did not want the measurements of very old people, or indeed of persons more than fifty years old.

Mr. Brabrook added that, as regards the supply of apparatus, the price of the cheaper kind of instrument for taking measurements was 1*l*. 6*s*., but there was a better one at 3*l*. 3*s*.

Dr. Garson remarked that the one at 1*l*. 6*s*. was quite good enough.

The Chairman said that in his opinion they had held a very useful Conference, and in concluding it he wished to express the hope that the delegates would bring its proceedings under the notice of their respective societies in as forcible and complete a way as possible. The custom of the Essex Field Club was to ask their delegate to send in a report of what had been done, and to publish it as soon as possible in the 'Essex Naturalist.' He hoped other Corresponding Societies would act in a similar manner.

A vote of thanks to the Chairman was proposed by Mr. Symons, seconded by Dr. Garson, and carried unanimously. The proceedings then terminated.

The Committee recommend the retention of all the Societies at present on the list, with the exception of the Royal Geological Society of Ireland, the Bedfordshire Archæological and Natural History Society, and the Liverpool Geographical Society, which have not complied with the regulations.

The Committee have pleasure in reporting that the Berwickshire Naturalists' Club, the Glasgow Archæological Society, and the Norfolk and Norwich Naturalists' Society have been added to the list of Corresponding Societies.

The Corresponding Societies of the British Association for 1894–95.

[An asterisk (*) indicates that the Society was represented at the Conference of Delegates at Nottingham. A dagger (†) indicates that the Society was represented at the Conference of Delegates at Oxford.

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
†Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5*s.*	10*s.*	Proceedings, annually.
*Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	257	None	1*l.* 1*s.*	Report and Proceedings, annually.
†Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. F. J. Bigger, M.R.I.A.	480	None	5*s.*	Report and Proceedings, annually.
†Berwickshire Naturalists' Club, 1831	Berwicksh. Nat. Club	Dr. J. Hardy, Old Cambus, Cockburnspath, N.B.	400	10*s.* 6*d.*	6*s.* to 7*s.* 6*d.*	History of the Berwickshire Naturalists' Club, annually
*†Birmingham Natural History and Philosophical Society, 1858	Birm. N. H. Phil. Soc.	W. P. Marshall, Mason College, Birmingham	266	None	1*l.* 1*s.*	Journal, monthly; Proceedings, annually.
*†Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	University College, Bristol. H. Percy Leonard	196	5*s.*	10*s.*	Proceedings, annually.
*Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	J. G. Wells, Selwood House, Shobnall Street, Burton-on-Trent	242	None	5*s.*	Annual Report. Transactions occasionally.
*†Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	450	None	10*s.* 6*d.*	Transactions, half-yearly.
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. R. Griffith	650	None	5*s.*	Annual Report. Proceedings, occasionally.
*†Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	310	1*l.* 1*s.* None	Members 31*s.* 6*d.*; Associates and Students 20*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	365	10*s.* 6*d.*	Minimum, 10*s.* 6*d.*	Transactions, annually.
†Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	100	None	1*l.* 1*s.*	Report and Transactions, annually.
*†Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H.	Public Hall, Croydon. T. D. Aldous	250	None	10*s.*	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc.	J. B. Bailey, 28 Eaglesfield Street, Maryport	500	None	6*s.*	Transactions, annually.
*†Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	N. M. Richardson, Montevideo, Chickerel, Weymouth	330	None	10*s.*	Proceedings, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Grey Friars', Dumfries	184	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
*†East Kent Natural History Society, 1857	E. Kent N. H. Soc.	19 Watling Street, Canterbury. Frank Baker	87	None	10*s.* 6*d.*	'South Eastern Naturalist,' occasionally.
*†East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 28 Whyte's Causeway, Kirkcaldy, N.B.	10 Societies, 982 Membs.	None	Assessment of 4*d.* per member	Proceedings, generally annually.

Edinburgh Geological Society, 1834	Edinb. Geol. Soc. .	H. M. Cadell, 5 St. Andrew Square, Edinburgh	237	10*s.* 6*d.*	12*s.* 6*d.*	Transactions, annually.
*†Essex Field Club, 1880 . . .	Essex F. C. . . .	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	400	10*s.* 6*d.*	15*s.*	'Essex Naturalist,' monthly.
*†Federated Institution of Mining Engineers	Fed. Inst. Min. Eng. .	M. Walton Brown, Neville Hall, Newcastle-upon Tyne	2,200	None	None	Transactions, about every two months.
†Glasgow Archæological Society, 1856	Glasgow Arch. Soc. .	207 Bath Street, Glasgow. J. Dalrymple Duncan and W. G. Black	313	None	12*s.* 6*d.*	Transactions, annually.
*†Glasgow, Geological Society of, 1858	Glasgow Geol. Soc. .	J. B. Murdoch, Capelrig, Mearns, Glasgow	250	None	10*s.*	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc. .	R. S. Wishart, M.A., and John Cairns, jun., 207 Bath Street, Glasgow	300	7*s.* 6*d.*	7*s.* 6*d.*	Proceedings and Transactions, annually.
†Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc. .	John Mayer, 207 Bath Street, Glasgow	675	1*l.* 1*s.*	1*l.* 1*s.*	Proceedings, annually; occasional papers.
*†Hampshire Field Club, 1885 . .	Hants F. C. . . .	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7*s.* 6*d.*	Proceedings, annually.
*†Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc. . .	John Hopkinson, F.L.S., The Grange, St. Albans	268	10*s.*	10*s.*	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C. .	A. J. Crosfield, Carr End, Reigate .	87	10*s.*	10*s.*	Proceedings, every two or three years.
Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc. .	J. Moran, Free Library Buildings, Inverness	170	None	5*s.*	Transactions, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland .	W. Lawson, 35 Molesworth Street, Dublin	90	None	1*l.*	Journal, annually.
*†Leeds Geological Association, 1874	Leeds Geol. Assoc. .	Mechanics' Institution. Wm. Lower Carter, F.G.S.	141	None	5*s.*	Transactions, annually.
*†Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	80 Municipal Buildings, Leeds. H. B. Wilson	179	None	6*s.*	Transactions, occasionally.
*Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, Town Museum, Leicester	312 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc. . .	R. C. F. Annett, Royal Institution, Liverpool	251	None	Resident 1*l.* 1*s.* Non-Res. and Students 10*s.* 6*d.*	Transactions, annually.
†Liverpool Geological Society, 1858 .	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	48	None	1*l.* 1*s.*	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. J. M. McMaster	182	None	1*l.* 1*s.*	Proceedings, annually.
Liverpool Microscopical Society, 1868	Liv'pool Mic. Soc. . .	Royal Institution. Andrew T. Smith, jun.	105	1*l.* 1*s.*	10*s.* 6*d.*	Report, annually.
*†Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc. .	Thomas J. Blanche, Yorkersgate, Malton, Yorkshire	84	None	5*s.*	Naturalists' Notes, monthly.
†Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	140	2*s.* 6*d.*	Gentlemen 6*s.*; Ladies 3*s.*	Yn Lioar Manninagh, quarterly
*†Manchester Geographical Society, 1885	Manch. Geog. Soc. .	Eli Sowerbutts, F.R.G.S., 44 Brown Street, Manchester	850	None	Members 1*l.* 1*s.*; Associates 10*s.* 6*d.*	Journal, quarterly.
*†Manchester Geological Society, 1838	Manch. Geol. Soc. .	James Tonge, 36 George Street, Manchester	200	None	1*l.*	Transactions, eight or nine parts per annum.
Manchester Statistical Society, 1833	Manch. Stat. Soc. . .	63 Brown Street, Manchester. Francis E. M. Beardsall and T. Gregory	170	10*s.* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick .	300	1*s.* 6*d.*	3*s.* and 5*s.*	Report, annually.

CORRESPONDING SOCIETIES, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
†Midland Union of Natural History Societies, 1877	Mid. Union . . .	T. V. Hodgson, 15 Lordswood Road, Harborne, Birmingham	13 Societies, 1,400 Membs.	—	3*d*. and 1*d*. per Member	'Midland Naturalist,' monthly.
†Norfolk and Norwich Naturalists' Society, 1869	Norf. Norw. Nat Soc. .	W. A. Nicholson, 3 Oxford Street, Norwich	266	None	5*s*.	Transactions, annually.
*†North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst. . .	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	900	None	21*s*. and 42*s*.	Transactions of Federated Institution of Mining Engineers, about every two months.
*†North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	411	5*s*.	5*s*.	Report and Transactions, annually.
*†Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc. . .	H. N. Dixon, East Park Parade, Northampton	250	None	10*s*.	Journal, quarterly.
†Nottingham Naturalists' Society, 1852	Nott. Nat. Soc. .	Nottingham Institute, 9 Shakespeare Street. F. R. Jackson	140	None	5*s*.	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst. .	J. Gardner, 3 County Place, Paisley	372	5*s*.	7*s*. 6*d*.	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc. .	G. F. Tregelles, 3 Market Place, Penzance	82	None	10*s*. 6*d*.	Report and Transactions, annually.
*†Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci. .	Tay Street, Perth. S. T. Ellison .	295	2*s*. 6*d*.	5*s*. 6*d*.	Transactions and Proceedings, annually.
†Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, B.Sc., 20 King Street South, Rochdale	249	None	6*s*.	Transactions, biennially.
Rochester Naturalists' Club, 1878	Rochester N. C. . .	John Hepworth, Union Street, Rochester	160	None	5*s*. and 10*s*.	'Rochester Naturalist,' quarterly.
†Somersetshire Archæological and Natural History Club, 1849	Som'setsh. A. N. H. Soc.	The Castle, Taunton. F. T. Elworthy	552	10*s*. 6*d*.	10*s*. 6*d*.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc. .	W. H. Finlay, Royal Observatory, Cape Town	68	None	2*l*.	Transactions, annually.
*†South London Microscopical and Natural History Club, 1871	S. London M. N. H. C.	Brixton Hall, Acre Lane, Brixton. H. Groves	100	None	10*s*.	Report, annually.
*†Tyneside Geographical Society, 1887	Tyneside Geog. Soc. .	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,000	None	10*s*.	Journal, half-yearly.
*†Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C. .	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	84	2*s*. 6*d*.	5*s*.	Proceedings, annually.
*†Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C. .	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	201	10*s*.	10*s*.	Transactions, biennially.
†Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	Wm. Lower Carter, F.G.S., Hopton, Mirfield	160	None	13*s*.	Proceedings, annually.
*†Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union .	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds	400 and 2,500 Associates	None	10*s*. 6*d*.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc. . .	Museum, York. T. S. Noble, F.G.S.	360	None	2*l*.	Report, annually.

Index of the more important Papers, and especially those referring to Local Scientific Investigations, published by the above-named Societies during the year ending June 1, 1894.

*** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Aitken, W.	On Special Applications of the Telephone	Glasgow Phil. Soc.	*Proc.*	XXIV.	184	1893
Aldous, T. D.	The Early History of the Microscope	Croydon M. N. H. C.	*Trans.*	For1892-93	1	„
Andson, Rev. W.	Meteorological Observations for 1892	Dum. Gal. N. H. A. Soc.	„	9	32	1894
Bayard, F. C.	Report of the Meteorological Sub-Committee for 1892	Croydon M. N. H. C.	„	For1892-93	28	1893
Bevan, Rev. J. O.	An Incident in the History of the Eiffel Tower	Woolhope N. F. C.	„	1890–1892	265	1894
Casartelli, Rev. L. C.	Belize, British Honduras: A Month's Meteorological Observations, and Notes of the Great Storm, July 6, 1893	Manch. Geol. Soc.	*Journal*	IX.	224	„
Clark, J. E.	Sunspot Period and the York Rainfall	Yorks. Phil. Soc.	*Report*	For 1893	33	„
Core, Prof. T. H.	Meteorology in relation to Geography	Manch. Geol. Soc.	*Journal*	VIII.	231	1893
Cresswell, A.	Records of Meteorological Observations taken at the Observatory of the Birmingham and Midland Institute	Birm. Phil. Soc.	*Proc.*	„	283	„
Crouch, W.	Astronomy in Wanstead: a Chapter of its Past History	Essex F. C.	*Essex Naturalist*	VII.	151	„
Donix, H. N.	Phenological Observations for 1892	N'ton. N. H. Soc.	*Journal*	„	248	„
Evans, F. G.	The Meteorology and Kindred Phenomena of 1892	Cardiff Nat. Soc.	*Trans.*	XXV. Pt.I.	47	„
Fergus, Dr. F.	The Light Sense in relation to Navigation	Glasgow Phil. Soc.	*Proc.*	XXIV.	177	„
Harvey, Rev. C. W.	Observations of Temperature and Rainfall taken at Throcking Rectory, Buntingford, 1880–89	Herts N. H. Soc.	*Trans.*	VII.	213	„
Henderson, J.	Rapid Traverser	Fed. Inst. Min. Eng.	„	5	199	„
Hopkinson, J.	Climatological Observations taken in Hertfordshire in the year 1891	Herts N. H. Soc.	„	VII.	157	„
„	Meteorological Observations taken at the Grange, St. Albans, during the year 1892	„ „	„	„	175	„

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Hopkinson, J.	Climatological Observations taken in Hertfordshire in the year 1892	Herts N. H. Soc.	*Trans.*	VII.	199	1893
" "	Report on the Rainfall in Hertfordshire in 1892	" "	"	"	203	"
" "	The Climate of Watford, deduced from Meteorological Observations taken during the ten years 1877–1886	" "	"	"	219	"
Jack, Prof. W.	Memoir of the late Dr. Robert Grant, Regius Professor of Astronomy in the University of Glasgow, and a former President of the Philosophical Society	Glasgow Phil. Soc.	*Proc.*	XXIV.	139	"
Jamieson, A.	Comparative Tests of Hellesen and E.C.C. Dry Battery Cells	" "	"	"	89	"
Maclean, M.	Some Experiments with a Ruhmkorff Coil	" "	"	"	1	"
Markham, C. A.	Meteorological Reports	N'ton. N. H. Soc.	*Journal*	VII.	238, 277 299	"
Meikle, A.	Lord Kelvin's new Electricity Meters	Glasgow Phil. Soc.	*Proc.*	XXIV.	170	"
Mitchell, Rev. J. C.	The Weather at Chester during the first ten months of 1893	Chester Soc. Nat. Sci.	"	IV.	275	"
Moore, H. C.	The Tidal Wave in the Wye and Severn, the Height of the Wye Tide, the Bore in the Severn, and a Well intermitting inversely with the Ebb and Flow of the Tide	Woolhope N. F. C.	*Trans.*	1890–92	316	1894
" "	Comparative Distances viewed from High Altitudes	" "	"	"	350	"
" "	A few Notes on the Earthquake of August 18, 1892	" "	"	"	354	"
Murphy, I. J.	The Division of Angles and Arcs of Circles	Belfast N. H. Phil. Soc.	*Report & Proc.*	For 1892-93	47	"
Murray, W. F.	On a new System of Firing Pottery Ware by the use of Gaseous Fuel	Glasgow Phil. Soc.	*Proc.*	XXIV.	64	1893
Poynting, Prof. J. H.	A History of the Method of Weighing the Earth	Birm. N. H. Phil. Soc.	"	IX.	1	1894
Richardson, N. M.	Returns of Rainfall in Dorset during 1892	Dorset N. H. A. F. C.	"	XIV.	201	1893
Society, The	Meteorological Observations taken at Coats Observatory, Paisley	Paisley Phil. Inst.	*Report*	"	—	"
Southall, H.	The Great Frosts of 1890-91	Woolhope N. F. C.	*Trans.*	1890–92	343	1894

Stroud, Prof. H.	Magnetic Declination and its Variations	N. Eng. Inst.	*Trans. Fed. Inst.*	7	268	„
Walker, A. O.	The Climate of Chester	Chester Soc. Nat. Sci.	*Proc.*	IV.	211	„
„ „	The Climate of the North Coast of Wales	„ „	„	„	215	„
„ „	The Spring and Summer of 1893 at Colwyn Bay	„ „	„	„	270	„
Weir, T.	Astronomy in relation to Geography	Manch. Geog. Soc.	*Journal*	VIII.	211	1893
Wells, J. G.	The Weather of 1892	Burt. N. H. Arch. Soc.	*Pamphlet*	—	—	„
Whitmell, C. T.	Space and its Dimensions	Cardiff Nat. Soc.	*Trans.*	XXV. Pt. I.	6	„
Wood, J. G.	The Height of Wye Tides, Variations of Absolute Level of High Water at different Points, the Bore in the Severn, the Bore in the Wye, the Intermitting Wells at Chepstow	Woolhope N. F. C.	„	1890–92	325	1894

Section B.—CHEMISTRY.

Bedson, Prof. P. P.	A Contribution to our Knowledge of Coal Dust: Part II.	N. England Inst.	*Trans. Fed. Inst.*	7	27	1894
Bedson, Prof. P. P., and J. W. McConnell	A Contribution to our Knowledge of Coal Dust: Part III.	„ „	„ „	„	32	„
Blackett, W. C.	The Combustion of Oxygen and Coal Dust in Mines	„ „	„ „	„	54	„
Clowes, Prof. F.	The Hydrogen-Oil Gas-Testing Safety Lamp	Chesterf. Mid. Count. Inst.	„ „	„	2	„
Gore, Dr. G.	On the Decomposition of Liquids by contact with Powdered Silica, &c.	Birm. N. H. Phil. Soc.	*Proc.*	IX.	24	„
Gresley, W. S.	Spontaneous Combustion in Coal Mines	Fed. Inst. Min. Eng.	*Trans.*	7	206	„
„ „	Notes on Outbursts of Soft Coal and Gas	Manch. Geol. Soc.	„	XXII.	429	1893
Kayll, A. C.	Mining Explosives: their Definition as Authorised under the Explosives Act (1875)	N. England Inst.	*Trans. Fed. Inst.*	6	346	„
Neate, P. J.	Aluminium	Rochester N. C.	*Roch. Naturalist*	II.	177	„
Settle, J.	Spontaneous Combustion in Coal Mines	Fed. Inst. Min. Eng.	*Trans.*	5	10	„
Stokes, A. H.	A Safety Lamp with Standard Alcohol-Flame Adjustment, for the Detection and Elimination of small Percentages of Inflammable Gas	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	„	462	„
Tilden, Prof. W. A.	Early Iron Working in the Highlands of Scotland	Birm. N. H. Phil. Soc.	*Proc.*	IX.	48	1894

Section C.—GEOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Aitken, H.	The Hilderston Silver Mine near Linlithgow	Fed. Inst. Min. Eng.	*Trans.*	6	193	1893
„ „	The Formation of the Earth's Crust and its Destruction	„ „	„	„	210	„
Banks, R. W.	Reminiscences of the Downton Sandstone	Woolhope N. F. C.	„	1890–92	390	1894
Bertrand, M.	The Correlation of the Coalfields of Northern France and Southern England	Fed. Inst. Min. Eng.	„	5	106	1893
Blackwell, G. G.	Notes on Bauxite of Co. Antrim and its Uses in the Manufacture	Manch. Geol. Soc.	„	XXII.	525	1894
Brodie, Rev. P. B.	Notice of a Section in the Lower Lias at the Cement Works near Rugby	Warw. N. A. F. C.	*Proc.*	38	17	„
„ „	Remarks on a Section in supposed Drift at Hillmorton, near Rugby	„ „	„	„	37	„
„ „	Notice of a Section in the Middle Lias at Napton	„ „	„	„	43	„
„ „	On additional Remains of Cestraciont and other Fish in the Green Marls immediately overlying the Red Marls of the Upper Keuper in Warwickshire; with an account of the equivalent Beds in Germany and the Tyrol	„ „	„	„	48	„
Browne, M.	A Contribution to the History of the Geology of the Borough of Leicester	Leicester Lit. Phil. Soc.	*Trans.*	III.	123	1893
Buckman, S. S.	The Top of the Inferior Oolite and a Correlation of Inferior Oolite Deposits	Dorset N. H. A. F. C.	*Proc.*	XIV.	37	„
Cadell, H. M.	The Geological Changes wrought by Man within the Forth Basin	Edinb. Geol. Soc.	*Trans.*	VI.	275	„
„ „	The Old Lakes of Edinburgh	„ „	„	„	287	„
Cameron, A. C. G.	The Geology, Mining, and Economic Uses of Fullers' Earth	Fed. Inst. Min. Eng.	„	6	204	„
Carter, W. L.	Reports of Field Excursions	Leeds Geol. Assoc.	„	VIII.	84	„
Cheetham, W.	A Trip round Scotland	„ „	„	„	52	„
Coates, H.	Opening Address	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	cxlix.	„
„ „	Presidential Address	„ „	„ „	„	clxvi.	„
Collins, A. L.	The Ghorband Lead Mines, Afghanistan	N. England Inst.	*Trans. Fed. Inst.*	6	494	„
Collins, J. H.	Illustrations of Cornish Fossils	Cornw. R. Geol. Soc.	*Trans.*	XI.	553	1894

Cornewall, Rev. Sir G. H.	The Formation of Travertine	Woolhope N. F. C.	"	1890–92	238	"
Cumming, L.	Some Observations on Mountain Débris	Liverpool Geol. Soc.	*Proc.*	VII.	87	1893
Cuttriss, S. W.	The Parallel Roads of Glen Roy	Leeds Geol. Assoc.	*Trans.*	VIII.	24	"
Dakyns, J. R.	A Sketch of the Geology of Nidderdale and the Washburn North of Blubberhouses	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	294	1894
" "	The Glacial Phenomena of Wharfedale between Bolton Abbey and Kettlewell	" "	"	"	299	"
Dawkins, Prof. W. Boyd	Geology in relation to Geography	Manch. Geol. Soc.	*Journal*	VIII.	226	1893
" "	On the South-Eastern Coalfield at Dover	" "	*Trans.*	XXII.	488	1894
De Rance, C. E.	On the Boring for Coal on the Freeholders' Estate at Hazel Grove	" "	"	"	452	"
Dickson, E.	Note on Section at Skillaw Clough, near Parbold	Liv'pool Geol. Soc.	*Proc.*	VII.	106	1893
Enys, J. D.	On the Action of Wind and Sand in Cutting Stone	Cornw. R. Geol. Soc.	*Trans.*	XI.	533	1894
Farrar, A.	The Coast between Eastbourne and Folkestone	Leeds Geol. Assoc.	"	VIII.	48	1893
Forsyth, Dr. D.	The General Geology of Scotland	" "	"	"	84	"
Fox, Howard	Presidential Address	Cornw. R. Geol. Soc.	"	XI.	495	1894
Fox-Strangways, C.	The Valleys of North-East Yorkshire and their Mode of Formation	Leicester Lit. Phil. Soc.	"	III.	333	"
Geikie, Sir A.	The Work of the Geological Survey	Fed. Inst. Min. Eng.	"	5	142	1893
Gibson, W.	Geology of the Southern Transvaal	" "	"	6	124	"
Goodchild, J. G.	The Minerals at Barnton	Edinb. Geol. Soc.	"	VI.	301	"
Greenwell, G. C., jun.	Bitumen from a Coal Seam at Poynton, near Stockport	Manch. Geol. Soc.	"	XXII.	444	1894
Gregory, Dr. J. W.	Catalogue of Jurassic Polyzoa in the York Museum	Yorks. Phil. Soc.	*Report*	For 93	58	"
Gregson, W.	In Memoriam: The late Rev. W. Collings Lukis	Yorks. Nat. Union	*The Naturalist*	For 1893	161	1893
Halse, E.	The Gold-bearing Veins of the Organos District, Tolima, U. S. Colombia	N. Eng. Inst.	*Trans. Fed. Inst.*	5	233	"
" "	Note on the Occurrence of Mercury at Quindiú, Tolima, U. S. Colombia	" "	" "	6	59	"
" "	Note on the Antimony Deposit of El Altar, Sonora, Mexico	" "	" "	"	290	"
Hardcastle, C. D.	Chalk and Flint	Leeds Geol. Assoc.	*Trans.*	VIII.	14	"
Harker, A.	Bibliography of Geology and Palæontology for the North of England, 1892	Yorks. Nat. Union	*The Naturalist*	For 1893	265	"
Hawkesworth, E.	Notes on some Withernsea Specimens	Leeds Geol. Assoc.	*Trans.*	VIII.	52	"
Heath, A. J., and C. L. Morgan	On the Fish Remains of the Lower Carboniferous Rocks of the Bristol District	Bristol Nat. Soc.	*Proc.*	VII.	80	"

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Henderson, J.	Sections exposed on the Barnton Railway	Edinb. Geol. Soc.	*Trans.*	VI.	297	1893
Hewitt, W.	Presidential Address: The Physical Conditions of the Aralo-Caspian Region as bearing on the Conditions under which the Triassic Rocks were formed	Liv'pool Geol. Soc.	*Proc.*	VII.	11	"
Hick, T.	In Memoriam: J. W. Davis	Yorks. Nat. Union	*The Naturalist*	For 1893	305	"
"	On *Calamostachys Binneyana*, Schimp	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	279	1894
Holgate, B.	Some Examples of Change in Rock caused by the Permeation of Underground Water	Leeds Geol. Assoc.	*Trans.*	VIII.	73	1893
Holland, P., and E. Dickson	Remarks on the Formation of Clay	Liv'pool Geol. Soc.	*Proc.*	VII.	108	"
Holmes, W. M.	On the Microscopic Structure of Hearthstone from Betchworth, Surrey	Croydon M.N.H.C.	*Trans.*	For 1892–3	17	"
Howard, F. T.	Note on the Effect of Fire on Bath Oolite	Cardiff Nat. Soc.	"	XXV.Pt.II.	43	1894
" "	On an Ichthyosaurus found at Penarth	" "	"	"	44	"
Hughes, Prof. T. McK.	Observations on the Silurian Rocks of North Wales	Chester Soc. Nat. Sci.	*Proc.*	IV.	141	"
" "	Caves and Cave Deposits	" "	"	"	161	"
Ingleby, J.	Corals and Coral Islands	Leeds Geol. Assoc.	*Trans.*	VIII.	9	1893
Johnston-Lavis, Dr. H. J.	The Ejected Blocks of Mount Somma	Edinb. Geol. Soc.	"	VI.	314	"
Kendall, P. F.	The Cause of the Ice Age	Leeds Geol. Assoc.	"	VIII.	53	"
" "	The Glaciation of Yorkshire	Yorks. Geol. Poly. Soc.	*Proc.*	XII.	275	1894
Kinahan, G. H.	On the Iron Ore Measures of County Antrim	Manch. Geol. Soc.	*Trans.*	XXII.	458	"
" "	On Boulder Clay Nodules and Ice-worn Stones	" "	" "	"	512	"
Kirkup, J. P.	Singareni Coalfield, Hyderabad, India	N. Eng. Inst.	*Trans. Fed. Inst.*	6	421	1893
La Touche, Rev. J. D.	Notes on the Asteroidea or Star Fishes of Church Hill Quarry, &c.	Woolhope N. F. C.	*Trans.*	1890-1892	35	1894
" "	The Passage or Transition Beds	" "	"	"	37	"
" "	The Geology of the Woolhope District	" "	"	"	160	"
" "	Igneous Rocks, and the Eruption of Diorite at Bartestree	" "	"	"	166	"
Lea, Rev. T. S.	The Physiography and Geology of the Dingle of Sapey Brook	" "	"	"	306	"

Lomas, J., and Capt. A. R. Dwerryhouse	The Glacial Deposits on the Shore of the Mersey, between Hale Head and Decoy Marsh	Liv'pool Geol. Soc.	*Proc.*	VII.	80	1893
„	On some Faults exposed in Arno Quarry	„ „	„	„	118	„
Lupton, A.	Geology of the West Yorkshire Coalfield	Fed. Inst. Min. Eng.	*Trans.*	7	137	1894
Mansel - Pleydell, J. C.	Presidential Address : Palæobotany	Dorset N. H. A. F. C.	*Proc.*	XIV.	1	1893
„	A further Note on the Dawlish 'Elephant Bed'	„ „	„	„	139	„
Miall, Prof. L. C.	The Distribution of Plants and Animals as affected by the past History of the Earth	Leeds Geol. Assoc.	*Trans.*	VIII.	74	„
Milne, J.	On Earth Pulsations and Mine Gas	Fed. Inst. Min. Eng.	„	5	203	„
Monckton, H. W.	Geological Notes in the Neighbourhood of Ongar, Essex	Essex F. C.	*Essex Naturalist*	VII.	87	„
„ „	On the Gravels near Barking Side, Wanstead, and Walthamstow, Essex	„ „	„ „	„	115	„
Moore, A. G.	Notes of a Mining Engineer's Visit to South Africa	„ „	„	„	190	„
Moore, R. T.	Recent Developments of the Hamilton Coalfield	Glasgow Phil. Soc.	*Proc.*	XXIV.	51	„
Morison, Dr. J.	Ice and its Work	Herts. N. H. Soc.	*Trans.*	VII.	147	„
Morris, T.	Geological, Manufacturing, and other Notes on Iron	Liv'pool E. Soc.	„	XIV.	84	„
Overend, J.	The Coalfields of Sonora, Mexico	Fed. Inst. Min. Eng.	„	7	230	1894
Peach, B. N., and J. Horne	On a Shelly Mound at Tongue Ferry, Sutherland	Edinb. Geol. Soc.	„	VI.	303	1893
„ „	The Occurrence of Shelly Boulder Clay in North Ronaldshay, Orkney	„ „	„	„	309	„
Peile, W.	Notes and Analyses of Iron Ores and Bauxite from the Crommelin Mines, Co. Antrim	Manch. Geol. Soc.	„	XXII.	522	1894
Piper, G. H.	Further Remarks on the Physical Geology of the Woolhope Valley	Woolhope N. F. C.	„	1890-92	164	„
„ „	Exposures suggested to the Geological Photographs' Committee for representation	„ „	„	„	359	„
Platnauer, H. M.	Appendix to List of Specimens in York Museum	Yorks. Phil. Soc.	*Report*	For 1893	46	„
„ „	Notes on Borings near York	„ „	„	„	56	„
Reade, T. M.	The Drift Beds of the Moel Tryfaen Area of the North Wales Coast	Liv'pool Geol. Soc.	*Proc.*	VII.	36	1893
Richards, E. P.	On Researches in the newly-discovered 'Acrodias Bed' in the Green Gritty Marls of the Upper Keuper at Shrewley, Warwickshire; chiefly upon its Extension	Warw. N. A. F. C.	„	38	54	1894

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Ricketts, Dr. C.	On some Conditions existing during the Formation of the Older Carboniferous Rocks	Liv'pool Geol. Soc.	*Proc.*	VII.	94	1893
Shaw, F. G.	Auriferous Conglomerates of Witwatersrandt	Fed. Inst. Min. Eng.	*Trans.*	5	169	"
Shone, W.	Subterranean Erosion, and some of its Effects	Chester Soc. Nat. Sci.	*Proc.*	IV.	252	1894
"	The Cause of Crateriform Sand Dunes and Cwms	" "	"	"	263	"
"	A Note on the Submerged Forest at Rhyl	" "	"	"	265	"
Somervail, A.	The Origin and Relations of the Lizard Rocks	Cornw. R. Geol. Soc.	*Trans.*	XI.	536	"
Stephens, F. J.	On some remarkable Contortions of Rocks at Rosemullion Head	" "	"	"	544	"
" "	On some Manilla Andesites	" "	"	"	551	"
Stirrup, M.	Further Notes on Boulders from the Coal Measures	Manch. Geol. Soc.	"	XXII.	321	1893
Tate, T.	Lake Country Rocks Microscopically described	Yorks. Nat. Union	*The Naturalist*	For 1893	247	"
"	The Yorkshire Boulders' Committee and its Seventh Year's Work	" "	" "	"	363	"
Teall, J. J. H.	On Greenstones associated with Radiolarian Cherts	Cornw. R. Geol. Soc.	*Trans.*	XI.	560	1894
Thompson, B.	Geological Notes	N'ton. N. H. Soc.	*Journal*	VII.	254	1893
Watson, C. J.	The Hemlock Stone	Birm. N. H. Phil. Soc.	"	I.	29	1894
Watts, W.	Singular Nodules and Ice-worn Stones found in the Boulder Clay of Piethorn Valley	Manch. Geol. Soc.	*Trans.*	XXII.	436	1893
Williams, C. H.	Practical Notes on the Mining of Iron Ores, Bauxite, &c., of Co. Antrim	" "	"	"	518	"
Wilson, A. P.	Minerals and Mining in Tasmania	N. Eng. Inst.	*Trans. Fed. Inst.*	7	276	"

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Adams, L. E.	The Mollusca of Penistone, South-West Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1893	315	1893
Ashdown, W. C.	A supposed Hybrid Grouse	Woolhope N. F. C.	*Trans.*	1890–92	378	1894
" "	Ornithology in Herefordshire from 1889 to 1893	" "	"	"	381	"
Baker, W. F.	The Yorkshire Naturalists' Union at Aysgarth	Yorks. Nat. Union	*The Naturalist*	For 1893	222	1893
" "	Formation of a Lincolnshire Naturalists' Union	" "	" "	"	253	"

" "	Lincolnshire Naturalists at Woodhall Spa	" "	" "	"	309	"
" "	Yorkshire Naturalists at Kirkley Moorside	" "	" "	"	317	"
" "	Yorkshire Naturalists' Union at Pocklington	" "	" "	For 1894	61	1894
Batters, E. A. L.	A Provisional List of the Marine Algæ of Essex and the adjacent Coast	Essex F. C.	*Essex Naturalist*	VIII.	1	"
Bennett, A.	The Genus Orobanche in Scotland	Dum. Gal. N. H. A. Soc.	*Trans.*	9	6	"
Bevan, Rev. J. O.	Certain useful Subjects of Scientific Investigation	Woolhope N. F. C.	"	1890–92	211	"
Birkenhead, G. A.	Some Lepidoptera of the Vale of Neath	Cardiff Nat. Soc.	"	XXV. Pt. I.	82	1893
Burgess, J. T.	An Account of some of the rarer Plants found in and around Spilsby, Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1893	325	"
Cambridge, Rev. O. P.	On new and rare British Spiders	Dorset N. H. A. F. C.	*Proc.*	XIV.	142	"
Charbonnier, H. J.	Notes on the Habits of the Larva of *Gracillaria syringella*	Bristol Nat. Soc.	"	VII.	132	"
Clarke, Miss G.	Lichens	Leicester Lit. Phil. Soc.	*Trans.*	III.	267	"
Clarke, W. E.	Further Notes on the Migration of the Yellow Wagtail	Yorks. Nat. Union	*The Naturalist*	For 1894	80	1894
Cole, W.	Locusts in Essex	Essex F. C.	*Essex Naturalist*	VII.	195	1893
Cooke, Dr. M. C.	The Fresh-water Algæ of Essex: a Preliminary List of Recorded Species	" "	" "	"	170	"
" "	Controverted Agarics	Woolhope N. F. C.	*Trans.*	1890–92	106	1894
" "	Fungi—Past, Present, and Future	" "	"	"	360	"
" "	Fungoid Pests of the Orchard	" "	"	"	366	"
Corbett, H. H.	Further Additions to the Doncaster List of Lepidoptera	Yorks. Nat. Union	*The Naturalist*	For 1893	369	1893
Cordeaux, J.	Some Stray Notes from the Yorkshire Coast in the Spring of 1893	" "	" "	"	203	"
" "	Disappearance of the Great Bustard in Lincolnshire	" "	" "	"	308	"
" "	Bird Notes from the Humber District, Summer and Autumn of 1893	" "	" "	"	357	"
" "	Bird Notes from the Humber District	" "	" "	For 1894	39	1894
" "	Occurrence of *Linota exilipes* (Coues) on the East Coast of Yorkshire	" "	" "	"	84	"
" "	Migration of the Yellow Wagtail	" "	" "	"	129	"
Cornewall, Rev. Sir G. H.	On the Names of Plants	Woolhope N. F. C.	*Trans.*	1890–92	74	"
Crossland, C.	Additions to the West Riding Fungus Flora	Yorks. Nat. Union	*The Naturalist*	For 1894	165	"

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Crouch, W.	On the Occurrence of *Crepidula fornicata*, L., off the Coast of Essex	Essex F. C.	*Essex Naturalist*	VIII.	36	1894
Dobie, W. H.	Birds of West Cheshire, Denbighshire, and Flintshire	Chester Soc. Nat. Sci.	*Proc.*	IV.	282	"
Douglas, W. D. R.	Note on the Genus Apion	Dum. Gal. N. H. A. Soc.	*Trans.*	9	126	"
Druce, G. C.	The Flora of Northamptonshire	N'ton. N. H. Soc.	*Journal*	VII.	161, 250, 292	1893
Druitt, C.	The Green Woodpecker	Bristol Nat. Soc.	*Proc.*	"	122	"
Drummond-Hay, Col. H. M.	Occurrence of the Hoopoe in the Tay District	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	cxlvii.	"
Emmet, J.	In Memoriam: Rev. J. W. Chaloner	Yorks. Nat. Union	*The Naturalist*	For 1894	113	1894
Evans, C. T.	In Memoriam: Charles Ashford	" "	" "	"	161	"
Eyre, Rev. L. W.	A new Hampshire Fungus	Hants F. C.	*Proc.*	II.	353	"
Fingland, J.	Nithsdale Willows	Dum. Gal. N. H. A. Soc.	*Trans.*	9	95	"
French, J.	Notes on the Seasons of 1893, principally in the Neighbourhood of Felstead	Essex F.C.	*Essex Naturalist*	VII.	188	1893
Friend, Rev. H.	A new Species of *Lumbricus*	Yorks. Nat. Union	*The Naturalist*	For 1893	295	"
" "	Rosa on the Revision of the Lumbricidi	" "	" "	"	349	"
Gibbs, A. E.	Notes on Lepidoptera observed in Hertfordshire	Herts N. H. Soc.	*Trans.*	VII.	187	"
" "	A List of Hertfordshire Hepaticæ	" "	"	"	233	"
Goodman, C. H.	Observations on the Emergence of the Crane Fly (*Tipula oleracea*)	Croydon M. N. H. C.	"	For 1892-93	20	"
" "	On the Mouths of Insects	" "	"	"	22	"
Hawkesworth, L.	Yorkshire Naturalists in Mid-Ribblesdale	Yorks. Nat. Union	*The Naturalist*	For 1894	7	1894
Hewett, W.	Lepidoptera in the Neighbourhood of York, 1893	" "	" "	"	13	"
" "	Occurrence of *Xanthia aurago* in South Yorkshire in 1893	" "	" "	"	116	"
Hey, Rev. W. C.	Forge Valley in Winter	" "	" "	For 1893	175	1893
" "	Specimen Days on the Yorkshire Coast	" "	" "	"	243	"
Hobkirk, C. P.	In Memoriam: George Brook, F.L.S.	" "	" "	"	353	"
Hughes, Rev. G.	New Forest Entomology	Hants F. C.	*Proc.*	II.	271	1894
Knubley, Rev. E. P.	The Protection of Wild Birds' Eggs	Yorks. Nat. Union	*The Naturalist*	For 1893	238	1893
Leach, R. E.	The Botany of Appleby and District	" "	" "	For 1894	27	1894
Lee, P. F.	Casuals and Aliens in the Dewsbury District in 1893	" "	" "	"	81	"

Lees, F. A., J. Farrah, and A. Millward	Additions and Corrections to the Nidderdale Flora	„ „	„ „	„	55	„
Lewis, H.	Notes on Birds observed in Hertfordshire during the year 1892	Herts N. H. Soc.	*Trans.*	VII.	161	1893
Ley, Rev. A.	Notes on a few of the more interesting Flowering Plants inhabiting the Brecon Beacons	Woolhope N. F. C.	„	1890–1892	86	1894
„ „	Florula of the Doward Hills—Mosses	„ „	„	„	132	„
„ „	First Contribution towards a Flora of Aberedw, Radnorshire	„ „	„	„	180	„
Lilford, Lord	Notes on the Ornithology of Northamptonshire for 1891	N'ton. N. H. Soc.	*Journal*	VII.	165	1893
„ „	Notes on the Ornithology of Northamptonshire for 1892	„ „	„	„	173	„
„ „	Notes on the Birds of Northamptonshire and Neighbourhood	„ „	„	„	197	„
Lovett, E.	Abnormal Forms and Variations in the Animal Kingdom	Croydon M. N. H. C.	*Trans.*	For 1892–3	10	„
Mackay, H.	Ornithological Notes	Dum. Gal. N. H. A. Soc.	„	9	137	1894
M'Andrew, J.	Botanical Notes for 1892	„ „ „	„	„	29	„
Marshall, W. P.	Notes on a Visit to the Scilly Isles and the Tresco Gardens	Birm. N. H. M. Soc.	*Mid. Naturalist*	XVI.	269	1893
Massee, G., and C. Crossland	Fungus Foray, with List of Fungi collected	Yorks. Nat. Union	*The Naturalist*	For 1894	68	1894
Mathew, Rev. M. A.	A Revised List of the Birds of Somerset	Somersetsh. A. N. H. Soc.	*Proc.*	XXXIX. Part 2	102	1893
Mawley, E.	Report on Phenological Phenomena observed in Hertfordshire during the year 1892	Herts N. H. Soc.	*Trans.*	VII.	182	„
Meade, R. H.	A few Remarks upon Diptera	Yorks. Nat. Union	*The Naturalist*	For 1894	17	1894
Meyrick, E.	Entomological Notes	Marlb. Coll. N. H. Soc.	*Report*	42	68	„
Miall, Prof. L. C.	In Memoriam: Professor A. Milnes Marshall	Yorks. Nat. Union	*The Naturalist*	For 1894	45	„
Moore, H. C.	Reports of the Local Fungus Forays	Woolhope N. F. C.	*Trans.*	1890–1892	98, &c.	„
Mosley, S. L.	Yorkshire Galls: Additional Species and New Localities	Yorks. Nat. Union	*The Naturalist*	For 1893	241	1893
Murray, Rev. R. P.	Further Notes on Dorset Rubi	Dorset N. H. A. F. C.	*Proc.*	XIV.	179	„
„ „	The Flora of Somerset	Somersetsh. A. N. H. Soc.	„	XXXIX. Part 3	1	„
Neale, J. J.	Notes on Recent Specimens taken by Local Trawlers	Cardiff Nat. Soc.	*Trans.*	XXV. Part 1	78	„
Newstead, R.	The Heron and Heronries of Cheshire and North Wales	Chester Soc. Nat. Sci.	*Proc.*	IV.	226	1894

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Newstead, R.	A Preliminary List of the Mammals of Cheshire and North Wales	Chester Soc. Nat. Sci.	*Proc.*	IV.	244	1894
,, ,,	Zoological Observations during the Spring and Summer of 1893	,, ,,	,,	,,	279	,,
Norton, Dr. J. A.	The Coloration of Cuckoos' Eggs	Bristol Nat. Soc.	,,	VII.	134	1893
Pettigrew, A.	Graft Hybridization	Cardiff Nat. Soc.	*Trans.*	XXV.Pt.II.	38	1894
Petty, L.	The Constituents of the North Lancashire Flora, 1597 (?)–1893: First Paper	Yorks. Nat. Union	*The Naturalist*	For 1894	117	,,
,, ,,	Ditto: Second Paper	,, ,,	,, ,,	,,	149	,,
Phillips, E. C.	A Supposed Hybrid Grouse	Woolhope N. F. C.	*Trans.*	1890-1892	377, 380	,,
Pilley, J. B.	The Collection of British Birds at Clungunford House	,, ,,	,,	,,	33	,,
Praeger, R. L.	Botanical Rambles in Co. Armagh	Belfast N. H. Phil. Soc.	*Report and Proc.*	For1892–93	34	,,
Price, J.	Vegetable Phosphorescence	Chester Soc. Nat. Sci.	*Proc.*	IV.	139	,,
Richardson, N. M.	Report on Observations on the Appearance of Birds, Insects, &c., and the Flowering of Plants in Dorset during 1892	Dorset N. H. A. F. C.	,,	XIV.	201	1893
Roberts, T. V.	Notes on some Hertfordshire Mammalia	Herts N. H. Soc.	*Trans.*	VII.	169	,,
Roebuck, W. D.	Bibliography of Lepidoptera in the North of England, 1890	Yorks. Nat. Union	*The Naturalist*	For 1893	177	,,
,, ,,	Yorkshire Naturalists' Union—Annual Meeting at Huddersfield	,, ,,	,, ,,	,,	233	,,
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,, ,,	Bibliography of Neuroptera and Trichoptera for the North of England, 1888–1892	,, ,,	,, ,,	,,	301	,,
,, ,,	Bibliography of Phanerogamic Botany for the North of England, 1889	,, ,,	,, ,,	For 1894	93	1894
,, ,,	Bibliography of Fresh-water Fishes of the North of England, 1889–1893	,, ,,	,, ,,	,,	141	,,
,, ,,	Bibliography of Birds of the North of England, 1891	,, ,,	,, ,,	,,	177	,,
Rogers, R.	Notes on our Native Plants: The Hazel	N'ton. N. H. Soc.	*Journal*	VII.	260	1893
Saunders, J.	Notes on the Mycetozoa, with a List of Species from Hertfordshire and Bedfordshire	Herts N. H. Soc.	*Trans.*	VII.	137	,,

Scott-Elliott, G. F.	The Influence of Insects on Flowers	Dum. Gal. N. H. A. Soc.	„	9	17	1894
„ „	Report on the Dumfries Herbarium	„ „	„	„	144	„
Shackleton, A., and T. Hebden	Additions to the Lichen Flora of the West Riding of Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1893	165	1893
Shone, W.	In Memoriam: George William Shrubsole	„ „	„ „	„	341	„
Sidgwick, N. V.	New Localities for Plants of the Lake District	„ „	„ „	For 1894	49	1894
Swinhoe, Col. C.	Protective Resemblance and Mimicry in Nature	Manch. Geog. Soc.	*Journal*	IX.	104	„
Thomas, T. H.	Botanical Notes during the Summer of 1892	Cardiff Nat. Soc.	*Trans.*	XXV. Pt. I.	76	1893
„ „	An Abnormal Rose	„ „	„	XXV. Pt. II.	81	1894
Turner, W. B.	Desmid Notes	Yorks. Nat. Union	*The Naturalist*	For 1893	313	1893
Vine, G. J., jun.	In Memoriam: George Robert Vine	„ „	„ „	„	333	„
Vize, Rev. J. E.	Teratology	Woolhope N. F. C.	*Trans.*	1890–1892	115	1894
„ „	The Turret Spider, the Mouse-eating Spider, and the Trap	„ „	„	„	372	„
Walker, A. O.	Notes on the Natural History of the District from 1879 to 1893	Chester Soc. Nat. Sci.	*Proc.*	IV.	203	„
Watkins, Rev. M. G.	The Collection of British Birds at Clungunford House	Woolhope N. F. C.	*Trans.*	1890–1892	30	„
Webb, W. M.	*Testacella scutulum*, Sowerby	Essex F. C.	*Essex Naturalist*	VII.	120	1893
Wensley, Rev. E. B.	Evolutionary Death	Rochester N. C.	*Roch. Naturalist*	II.	193	„
West, W., and G. S. West.	Notes on the Fresh-water Algæ of the East Riding of Yorkshire	Yorks. Nat. Union	*The Naturalist*	For 1893	211	„
White, Dr. F. B.	Account of Summer Excursions, 1892	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	clii.	„
Whitlock, F. B.	Bird Notes from the Mid-Trent Valley in 1893	Yorks. Nat. Union	*The Naturalist*	For 1894	1	1894
„ „	Further Notes on the Migration of the Yellow Wagtail	„ „	„ „	„	77	„
„ „	The Migration of the Yellow Wagtail	„ „	„ „	„	175	„
Wilkinson, H. J.	Herbarium Notes	Yorks. Phil. Soc.	*Report*	For 1893	36	„
Wilkinson, W. H.	Life History of the Diamond-back Moth (*Plutella cruciferarum*)	Mid. Union	*Mid. Naturalist*	XVI.	169	1893
„ „	Lichens of the Isle of Man	Birm. N. H. M. Soc.	„ „	„	245, 272	„
Wilson, Rev. G.	List of Glenluce Plants	Dum. Gal. N. H. A. Soc.	*Trans.*	9	38	1894
Wood, Dr. J. H.	The Nepticulæ of the Woolhope District	Woolhope N. F. C.	„	1890–1892	257	„
Woodruffe-Peacock, Rev. E. A.	A Study of Seed Dispersion in Lincolnshire	Yorks. Nat. Union	*The Naturalist*	For 1894	19	„
„ „	A Critical Catalogue of Lincolnshire, from all Known Sources: Part I.	„ „	„ „	„	85	„
„ „	Ditto: Part II.	„ „	„ „	„	133	„

Section E.—GEOGRAPHY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Ainsworth, J.	Machakos, I. B. E. A.	Manch. Geog. Soc.	*Journal*	IX.	204	1894
Ballantine, Major R. F.	The Voyages of Columbus	„ „	„	„	126	„
Core, Prof. T. H.	Meteorology in Relation to Geography	„ „	„	VIII.	231	1893
Crouch, W.	Dr. Fridtjof Nansen: What he has done and what he proposes to do	Rochester N. C.	*Roch. Naturalist*	II.	209	1894
Dawkins, Prof. W. Boyd	Geology in Relation to Geography	Manch. Geog. Soc.	*Journal*	VIII.	226	1893
Foster, Capt. H.	Notes on the Geography, Government, and inhabitants of Uganda, with a Sketch of its History to 1892	„ „	„	„	266	„
Fretton, W. G.	The Waters of the Arden: A Sketch of its Springs, Wells, Rivers, Lakes, Pools, and Marshes within the Basin of the Avon	Warw. N. A. F. C.	*Proc.*	38	19	1894
Halligey, Rev. J. T. F.	The Yoruba Country, Abeokuta, and Lagos	Manch. Geog. Soc.	*Journal*	IX.	28	1893
Hamer, W.	Wensleydale	„ „	„	„	217	„
Hausa Association	The Central Soudan	„ „	„	„	195	„
Jackson, F. C.	Polar Exploration	Tyneside Geog. Soc.	„	II.	279	„
Markham, C. R.	Peru	„ „	„	„	215	„
Mellor, E. W.	The Lower Loire	Manch. Geog. Soc.	„	IX.	1	„
Mennell, H. T.	Notes on Norway	Croydon, M. N. H. C.	*Trans.*	For 1892–3	25	„
Military Intelligence Department	Hints on Reconnaissance Mapping for Explorers in Unsurveyed Countries	Manch. Geog. Soc.	*Journal*	IX.	49	„
Monaco, Prince Albert of	Project for Meteorological Observations in the Atlantic	„ „	„	„	82	„
Morgan, E. D.	Notes on the Early Discovery of Australia	„ „	„	VIII.	238	„
Nadaillac, Marquis de	The Extreme Heat and Cold endured by Man	„ „	„	IX.	211	1894
Oldham, R. D.	The River Valleys of the Himalayas	„ „	„	„	112	„
Parke, Surgeon T. H.	Uganda	Tyneside Geog. Soc.	„	II.	174	1893
Redmayne, J.	A Tour round the World	Leeds Geol. Assoc.	*Trans.*	VIII.	34	„
Redway, J. W.	The Influence of Rainfall on Commercial Development: A Study of the Arid	Manch. Geog. Soc.	*Journal*	IX.	135	1894

Reed, J. H.	From England to Japan	„ „	„	„	221	„
Roberts, Lord	Delhi, the Mogul Capital of India, and its Siege in 1857	Tyneside Geog. Soc.	„	II.	255	1893
Roeder, C.	Notice of Earliest Geographical Class Lectures in Manchester	Manch. Geog. Soc.	„	IX.	75	„
Ross, A.	Exploration of the Amazonian Provinces of Central Peru	Glasgow Phil. Soc.	*Proc.*	XXIV.	148	„
Selous, F. C.	Travel and Sport in South Africa	Manch. Geog. Soc.	*Journal*	IX.	45	„
„	Twenty Years in Zambesia	Tyneside Geog. Soc.	„	II.	155	„
„	The History of the Matabele, and the Cause and Effect of the Matabele War	„ „	„	„	230	„
Sowerbutts, E.	Africa	Manch. Geog. Soc.	„	IX.	148	1894
„	The British Association at Nottingham, 1893	„ „	„	„	193	„
Swan, R. M. W.	The Geography and Ethnology of Mashonaland, with a brief Account of the Ruins of Zimbabwe	Glasgow Phil. Soc.	*Proc.*	XXIV.	29	1893
Thomson, J. P.	The Melanesian Plateau	Manch. Geog. Soc.	*Journal*	IX.	213	1894
Trevor-Bathye, A.	A Proposed Visit of Exploration to Vaigatz Island (Novaya Zemblya)	„ „	„	„	131	„
Waddington, W. A.	Sicily	„ „	„	VIII.	245	1893
Weir, T.	Astronomy in relation to Geography	„ „	„	„	211	„
Whitehouse, Cope	Middle Egypt from Ptolemaic Maps and Modern Surveys	„ „	„	IX.	143	1894
Williams, Capt.	Uganda and its People	„ „	„	VIII.	278	1893
Wragge, C. L.	The Floods at Brisbane	„ „	„	IX.	88	„

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Addison, W. H.	The Education of the Deaf and (so-called) Dumb	Glasgow Phil. Soc.	*Proc.*	XXIV.		1893
Bailey, W. F.	Government Valuation of Ireland	Stat. Soc. Ireland	*Journal*	X.	651	„
Barrington, R. M.	Notes on Prices of Irish Agricultural Produce	„ „	„	„	679	„
Bastable, Prof. C. F.	The Difficulties of Bimetallism	„ „	„	„	664	„
Binns, G. J.	Mining in New Zealand: Part III. Coal Mining	Fed. Inst. Min. Eng.	*Trans.*	5	31	„
Broadfield, E. J.	The Future of the Voluntary Schools	Manch. Stat. Soc.	„	1893-94	71	1894
Browne, G. W.	On the Planning of Public Libraries	Glasgow Phil. Soc.	*Proc.*	XXIV.	240	1893
Chesneau, G.	The Oil Shale Industry of France	Fed. Inst. Min. Eng.	*Trans.*	7	180	1894
Davidson, M.	On the Elements of Profits	Glasgow Phil. Soc.	*Proc.*	XXIV.	73	1893

Section F.—ECONOMIC SCIENCE AND STATISTICS (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Fogg, W.	Strikes and Economic Fallacies	Manch. Stat. Soc.	*Trans.*	1893-94	1	1894
Hoskold, H. D.	Notes upon a Practical Method of ascertaining the Value or Price to be paid for Zinc	Fed. Inst. Min. Eng.	"	5 7	93 222	1893 1894
Lewis, G.	Presidential Address	" "	"	5	2	1893
Love, Dr. J. K.	The Education of the Deaf and (so-called) Dumb	Glasgow Phil. Soc.	*Proc.*	XXIV.	117	"
Mann, J., jun.	Reformed Public Houses: Notes upon the Scandinavian Licensing Systems and the Bishop of Chester's recent Proposals	" "	"	"	9	"
Mayer, J.	Obituary of John Jex Long	" "	"	"	237	"
Merttens, F.	The Hours and the Cost of Labour in the Cotton Industry at Home and Abroad	Manch. Stat. Soc.	*Trans.*	1893-94	125	1894
Mitchell, F. W. H.	Obituary of Thomas William Embleton	Fed. Inst. Min. Eng.	"	7	222	"
Moore, F.	Magistrates' Law, and suggested Increase of Jurisdiction and Powers	Stat. Soc. Ireland	*Journal*	X.	671	1893
Morison, J.	Limestone Mining in Scotland	Fed. Inst. Min. Eng.	*Trans.*	6	199	"
Neild, E.	The Inebriate Acts of 1879–1880 in Theory and Practice, with a suggested Amendment	Manch. Stat. Soc.	"	1893-94	91	1894
Rhodes, Dr. J. M.	The Objective Causes of Poverty	" "	"	"	43	"
Russell, Dr. J. B.	Obituary of W. R. W. Smith	Glasgow Phil. Soc.	*Proc.*	XXIV.	206	"
" "	Obituary of Sir Michael Connal	" "	"	"	211	"
Sheldon, Dr. C.	Education: A Critical Examination of the Theory and Practice of Dr. Arnold, of Rugby	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1892-93	75	1894
Steavenson, A. L.	Presidential Address	N. Eng. Inst.	*Trans. Fed. Inst.*	6	273	"
Sulley, P.	Trade Tokens	Dum. Gal. N. H. A. Soc.	*Trans.*	9	25	1894
Windle, Prof. B. C. A.	The Modern University	Birm. Phil. Soc.	*Proc.*	VIII.	185	1893

Section G.—MECHANICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Pub-lished
Armour, L. H.	Submarine Telegraphy	Tyneside Geog. Soc.	*Journal*	II.	183	1893
Bannister, M. C.	Description of Cold Storage Works and other similar Installations	Liv'pool E. Soc.	*Trans.*	XIV.	189	"
Barnes, A.	Presidential Address	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	5	457	"

Baum, F.	The Baum Coal-Washing Machinery	Fed. Inst. Min. Eng.	" "	7	156	1894
Bottomley, Dr. J. T.	The late Professor James Thomson, LL.D., D.Sc., C.E., F.R.S.	Glasgow Phil. Soc.	*Proc.*	XXIV.	220	1893
Capell, Rev. G. M.	Manometric Efficiency of Fans	N. Eng. Inst.	*Trans. Fed. Inst.*	5	252	"
Charleton, A. G.	The Choice of Coarse and Fine Crushing Machinery and Processes of Ore Treatment:					
	Part III. Silver	" "	" "	"	271	"
	Part IV. Gold	" "	" "	6	69	"
	Part V. Gold Milling	" "	" "	"	295	"
	Part VI. Gold Milling	" "	" "	"	457	"
	Part VII. Medium, Coarse, and Fine Crushing Stamps	" "	" "	7	67	1894
Collins, A. L.	Fire-setting: the Art of Mining by Fire	Fed. Inst. Min. Eng.	*Trans.*	5	82	1893
Conradi, J. F.	Description of Petroleum Engine, with Tests	Liv'pool E. Soc.	"	XIV.	106	"
Deacon, G. F.	A Sketch of the Vyrnwy Works	" "	"	"	49	"
Farren, G.	On Forces used by Engineers considered as Velocities	" "	"	"	138	"
Fitzgerald, Prof. M. F.	Electric Power Supply on Tramways at Patterson, New Jersey	Belfast N. H. Phil. Soc.	*Report & Proc.*	For 1892-93	81	1894
Fox, F.	Local Engineering Works in progress or contemplated	Bristol Nat. Soc.	*Proc.*	VII.	105	1893
Goodman, Prof.	The Transmission of Power by Compressed Air	Fed. Inst. Min. Eng.	*Trans.*	7	233	1894
Greenhill, J. H.	Electricity as an Illuminant	Belfast N. H. Phil. Soc.	*Report & Proc.*	For 1892-93	19	"
Harvey, J. W. I.	Draught in Marine Boilers	Bristol Nat. Soc.	*Proc.*	VII.	118	1893
Hele-Shaw, Prof. H. S.	The Graphical Method of Solving Engineering Problems	Liv'pool E. Soc.	"	XIV.	173	"
Higson, C. H.	The Walker Indestructible Fan and Engines	Manch. Geol. Soc.	"	XXII.	468	1894
Hughes, H. W.	Photography in Mines	Fed. Inst. Min. Eng.	"	7	164	"
Johnston, R. E.	Inaugural Address	Liv'pool E. Soc.	"	XIV.	1	1893
Leach, C. C.	Corliss-Engined Fan at Seghill Colliery	N. Eng. Inst.	*Trans. Fed. Inst.*	6	48	"
Lynde, J. H.	Automatic Sprinklers	Liv'pool E. Soc.	*Trans.*	XIV.	125	"
Maginnis, A. J.	The Development of the Machinery of Atlantic Liners	" "	"	"	18	"
Morris, T.	Geological, Manufacturing, and other Notes on Iron	" "	"	"	84	"
Murgue D.	The Friction of, or Resistance to, Air Currents in Mines	Fed. Inst. Min. Eng.	"	6	135	"
Murgue, D.	The Friction of, or Resistance to, Air Currents in Mines: Appendix	" "	"	7	211	1894

Section G.—MECHANICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Pierce, E. W.	Engineering Contracts	Liv'pool E. Soc.	*Trans.*	XIV.	212	1893
Saint, W.	On recent Improvements in Mining Machinery and Appliances	Manch. Geol. Soc.	„	XXII.	404	„
Seward, E.	Presidential Address: A proposed new Railway Connection of South Wales and London	Cardiff Nat. Soc.	„	XXV. Pt. II.	62	1894
Spencer. W.	The Support of Buildings	Fed. Inst. Min. Eng.	*Trans.*	5	188	1893
Stokes, A. H.	An Improved Water Gauge	Chesterf. Mid. Count. Inst.	*Trans. Fed. Inst.*	5	474	1893
Wordsworth, T.	Notes on Coal-getting by Machinery.	Fed. Inst. Min. Eng.	*Trans.*	7	149	1894

Section H.—ANTHROPOLOGY.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Allen, Prof. F. J.	The Origin of the Name 'Frome'	Som'setsh. A. N. H. Soc.	*Proc.*	XXXIX. Pt. II.	169	1893
Andrews, W.	Ancient Earthworks in Warwickshire, &c.	Warw. N. A. F. C.	„	38	45	1894
Arnott, S.	Plant Superstitions	Dum. Gal. N. H. A. Soc.	*Trans.*	9	78	„
Bankes, W. A.	The Recent Discovery of Human Remains at Wareham House, Dorchester	Dorset N. H. A. F. C.	*Proc.*	XIV.	105	1893
Barnes, Rev. W. M.	Maiden Castle	„ „	„	„	55	„
Bird, C.	A new Chapter on the Antiquity of Man	Rochester N. C.	*Roch. Naturalist*	II.	225	1894
„ „	Remarks on Bones found in the District	„ „	„ „	„	229	„
Black, Dr. G. F.	Scottish Antiquities in the Grierson Museum, Thornhill	Dum. Gal. N. H. A. Soc.	*Trans.*	9	108	„
Bulleid, A.	A British Village of Lake or Marsh Dwellings in Somerset	Cardiff Nat. Soc.	„	XXV. Pt. II.	50	„
Chinnock, Dr. E. J.	The Burial Place of Alexander the Great	Dum. Gal. N. H. A. Soc.	„	9	142	„
Cole, W.	Report of Visit to Deneholes in Hangman's Wood, near Grays	Essex F. C.	*Essex Naturalist*	VII.	143	1893
Coles, F. R.	Cup and Ring Marks	Dum. Gal. N. H. A. Soc.	*Trans.*	9	8	1894
Crofton, H. T.	Vestiges of Village Communities	Manch. Geog. Soc.	*Journal*	IX.	91	„
Crouch, W.	Ancient Entrenchments at Uphall, near Barking, Essex	Essex F. C.	*Essex Naturalist*	VII.	131	1893

Day, G.	Notes on Essex Dialect and Folk Lore, with some Account of the Divining Rod	„ „	„ „	VIII.	71	1894
Elwes, Capt. G. R.	The New Forest	Dorset N. H. A. F. C.	*Proc.*	XIV.	62	1893
Gray, W.	Traces of Primitive Man in North of Ireland	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1892-93	45	1894
Griffith, R. W. S.	The Gipsies of the New Forest	Hants F. C.	*Proc.*	II.	277	„
Lovett, E.	On some remarkable Fire-making Appliances from Rajpootana	Croydon M. N. H. C.	*Trans.*	„	21	1893
Meyrick, E.	Anthropometrical Statistics of Members of Marlborough College	Marlb. Coll. N. H. Soc.	*Report*	42	126	1894
Norris, H.	The Place-name 'Frome'	Som'setsh. A. N. H. Soc.	*Proc.*	XXXIX. Part II.	31	1893
Onslow, Rev. P.	Place-names of the Neighbourhood of Sapey	Woolhope N. F. C.	*Trans.*	1890–92	311	1894
Paul, J. D.	St. John's Stone	Leicester Lit. Phil. Soc.	„	III.	262	1893
Prowse, Dr. A. B.	Some Ancient British Remains on Clifton Down	Bristol Nat. Soc.	*Proc.*	VII.	93	„
Shore, T. W.	The Candover Valley and its Prehistoric Inhabitants	Hants F. C.	„	II.	283	1894
Starke, J. G. H.	Kirns in Scotland	Dum. Gal. N. H. A. Soc.	*Trans.*	9	13	„
Stradling, A.	Man and Ape	Herts N. H. Soc.	„	VII.	xxxiv.	„
Thomas, T. H.	Inscribed Stones of Glamorganshire	Cardiff Nat. Soc.	„	XXV. Pt. I.	34	1893
Udal, J. S.	Dorsetshire Birth, Death, and Marriage Customs and Superstitions	Dorset N. H. A. F. C.	*Proc.*	XIV.	182	„
Windle, Prof. B. C. A.	On the Physical Characters of the Boys at King Edward's Schools, Birmingham, and at certain other Public Schools	Birm. Phil. Soc.		VIII.	216	„
Young, R. M.	Antiquarian Notes on Bushfoot and Ballymagarry	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1892-93	37	1894

Section I.—PHYSIOLOGY.

Collinge, W. E.	Note on the Lateral Canal System of *Polypterus*	Birm. Phil. Soc.	*Proc.*	VIII.	255	1893
„ „	The Lateral Canal System of *Lepidosteus osseus*	„ „	„	„	263	„
„ „	The Morphology of the Sensory Canal System in some Fossil Fishes	„ „	„	IX.	58	1894

Report on the Present State of our Knowledge of Thermodynamics.
By G. H. BRYAN.

PART II.—THE LAWS OF DISTRIBUTION OF ENERGY AND THEIR LIMITATIONS.
(*With an Appendix by* Prof. LUDWIG BOLTZMANN.)

INTRODUCTION.

1. THIS Report deals primarily with the Boltzmann-Maxwell Law and Maxwell's Law of Partition of Kinetic Energy, which form the basis of the Kinetic Theory of Gases. One of the main points kept in view has been to show where to draw the line between dynamical systems which do and dynamical systems which do not satisfy the laws in question.

Since the appearance of the first Report[1] several papers have appeared which have thrown a somewhat different light on certain aspects of the subject, and have thus materially assisted in crystallising our knowledge of this branch of Thermodynamics into a definite form. In order to prevent unnecessary controversy, I have, as far as possible, avoided drawing conclusions from arguments of a vague and theoretical nature. Where, however, results are based on purely mathematical calculations they must be understood to be liable to modification should further examination show the calculations to be faulty or inaccurate. It is necessary to mention this, as one of the investigations cited in Part I. has subsequently been found to be incorrect, with the result of very materially altering our views on the question at issue.[2]

A great advance in the present subject is due to the extension of the use of generalised co-ordinates, by which greater generality has been given to results and the analysis much simplified, as a comparison of Boltzmann's early papers with modern writings abundantly testifies. A further simplification has been effected by the use of the Jacobian notation.

For convenience I have in places written $\exp - hE$ for $\exp(-hE)$ or e^{-hE}.

The present Report is divided into three sections. In Section I. Maxwell's Law of Partition of Energy is regarded in the aspect of a general dynamical theorem, without reference to any particular applications, and without taking into account the effect of collisions. Section II. treats of the Boltzmann-Maxwell Law for a system of bodies colliding with one another indiscriminately, and partaking of the nature of gas molecules. Section III. deals briefly with certain researches connecting the Boltzmann-Maxwell Law with the Theory of Probability, the Virial Equation, and the Second Law of Thermodynamics.

SECTION I.—NON-COLLIDING SYSTEMS.

Clerk Maxwell's Investigations.

2. Clerk Maxwell's investigations[3] have played such a prominent part in the literature of the Kinetic Theory that I think it desirable to recapitulate his paper briefly, so as to show more clearly what assumptions he made and how much he actually proved.

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[1] *Cardiff Report*, 1891, pp. 85-122.

[2] The results stated in the first twelve lines of Part I. Section III. § 44 are now known to be erroneous. See also §§ 36, 37 below.

[3] 'On Boltzmann's Theorem of the Average Distribution of Energy in a System of Material Points,' *Trans. Camb. Phil. Soc.*, xii. 1879.

It may be safely asserted that a large portion of our progress in the present subject has been made, first, by showing that Maxwell's demonstrations are faulty and unsatisfactory, and subsequently by discovering fresh methods of proof, which, while leading to the same general conclusions, show more clearly the limitations and conditions under which these conclusions hold good. In this process of destruction and reconstruction a large amount of literature has accumulated, and I shall endeavour in the present Report to unearth from the general mass the main results to which these papers tend.

3. Maxwell claims that his theorem is applicable to any dynamical system whatever. 'The material points may act on each other at all distances and according to any law which is consistent with the equation of energy, and they may also be acted on by any forces external to the system, provided these also are consistent with that law. The only assumption which is necessary for the direct proof is that the system, if left to itself in its actual state of motion, will sooner or later pass through every phase which is consistent with the equation of energy.'[1]

4. Instead, however, of a single system, Maxwell considers a large number of independent dynamical systems, similar in every respect, each defined by its n co-ordinates $(q_1, \ldots q_n)$ and the corresponding n momenta $(p_1, \ldots p_n)$. Each system is capable of passing through every phase which is consistent with the equation of energy, and it is thus assumed that *all the systems have the same energy*. In the case of a free system unacted on by external forces, the six components of linear and angular momentum remain constant, and Maxwell assumes that *these are the same for all systems.*

5. Taking the 'action' of the system during any period of the motion, he employs this function to establish the determinantal relation between the multiple differentials of the co-ordinates and momenta at the beginning and end of any interval, and thus establishes the relation

$$\frac{\partial(p_1', \ldots p_n', q_1', \ldots q_n')}{\partial(p_1, \ldots p_n, q_1, \ldots q_n)}=1 \quad . \quad . \quad . \quad (1)$$

from which he deduces that, if the energy E be kept constant, so that p_1 can be expressed as a function of the $n-1$ other p's, then

$$\frac{\partial(p_2', \ldots p_n', q_1' \ldots q_n')}{\partial(p_2, \ldots p_n, q_1, \ldots q_n)}=\frac{\dot{q}_1'}{\dot{q}_1} \quad . \quad . \quad (2)$$

6. Hence it follows that, if the systems are so distributed that the number which initially have their co-ordinates and momenta within the limits of the multiple differential $dp_2 \ldots dp_n\, dq_1 \ldots dq_n$ be

$$\frac{\mathrm{NC}}{\dot{q}_1} dp_2 \ldots dp_n\, dq_1 \ldots dq_n \quad . \quad . \quad . \quad (3)$$

their total energies being all equal and C a constant, then the same expression gives the law of distribution at any subsequent time. Maxwell says: 'We have found one solution of the problem of finding a steady distribution; whether there may be other solutions remains to be investigated.'

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[1] *Loc. cit.*, p. 548

7. He next assumes that the momenta (now denoted by $a_1, \ldots a_n$) may be so chosen as to reduce the kinetic energy to a sum of squares, or

$$T=\tfrac{1}{2}\sum\mu_r a_r^2 \quad . \quad . \quad . \quad . \quad . \quad (4)$$

With this assumption, he integrates (3) with respect to the momenta, and finds by Dirichlet's method

$$\frac{\int \dot{b}^{-1}\,da_2\ldots da_{n-1}}{\int \dot{b}^{-1}\,da_2\ldots da_n}=\frac{2^{-\frac{1}{2}}\Gamma(\frac{1}{2}n)}{\Gamma(\frac{1}{2})\Gamma[\frac{1}{2}(n-1)]}\,\frac{(E-V-\frac{1}{2}\mu_n a_n^2)^{\frac{1}{2}(n-3)}}{(E-V)^{\frac{1}{2}(n-2)}}\,\mu_n^{\frac{1}{2}}$$

where $\dot{b}_1=\mu_1 a_1$. Hence he infers that if $k_n=\frac{1}{2}\mu_n a_n^2$ is the part of the kinetic energy arising out of the momentum a_n, then the number of systems *in a given configuration*, in which k_n lies within limits differing by dk_n, is

$$\frac{\Gamma(\frac{1}{2}n)}{\Gamma(\frac{1}{2})\Gamma[\frac{1}{2}(n-1)]}\,\frac{(E-V-k_n)^{\frac{1}{2}(n-3)}}{(E-V)^{\frac{1}{2}(n-2)}}\,k_n^{-\frac{1}{2}}\,dk_n \quad . \quad . \quad (5)$$

and that since this expression only involves k_n, therefore the law of distribution of the kinetic energy is the same for all the momenta. Multiplying the above expression by k_n, and integrating from $k_n=0$ to $k_n=T=E-V$, we find that the mean value of k_n is

$$K=\frac{1}{n}(E-V)=\frac{1}{n}T \quad . \quad . \quad . \quad (6)$$

the maximum value being of course equal to T, because the portions of the kinetic energy due to the other momenta cannot be negative. Hence Maxwell infers 'that the average kinetic energy corresponding to any one of the variables is the same for every one of the variables of the system.' This result is commonly called *Clerk Maxwell's Theorem.*

8. In Part II. of the paper Maxwell deals with a free system, consisting of n particles not acted on by external forces. For such a system not only the energy but also the velocity-components of the centre of mass and the components of angular momentum round this point in any three fixed directions will be constant throughout the motion. Maxwell therefore assumes them the same for every system. Under these circumstances the $3n$ momentum-components of the system are not all independent, but seven of them can be expressed in terms of the rest by means of the seven equations of condition, and the law of permanent distribution is expressible in terms of the multiple differential of the $3n$ co-ordinates and $3n-7$ of the velocity components of the particles. The algebra is very long and laborious, and need not be examined in detail here. The objections to Maxwell's investigations can be much more easily discussed and criticised with reference to the simpler case considered in Part I., and the law of distribution in a free system can be treated more simply by alternative methods (*vide* §§ 16–18, § 45, and appendices A, B below).

The Assumption that the System passes through every Phase consistent with the Equation of Energy.

9. This assumption probably presents greater difficulties than any other part of the Kinetic Theory, and it is therefore advisable to commence by stating under what circumstances it requires to be made

The whole of Maxwell's demonstration, and most of the investigations of Boltzmann,[1] Watson,[2] and other writers on the same subject, are based on the consideration of an infinitely large number of independent systems, similar in every respect, whose co-ordinates and momenta at any instant are distributed according to a fixed law, and the object is to find what this distribution must be in order that it may be independent of the time and unaffected by the motions of the systems. I cannot see that these investigations anywhere assume that *each individual system* passes through every possible phase. At each instant there must be *some* systems in every possible phase; but a distribution would obviously be permanent—and very much so indeed—in which each system always remained in the same phase, and never passed into any other phase.

10. The assumption first confronts us when we attempt to pass from the consideration of a large number of systems to that of a single system, *i.e.*, if, having investigated the result of averaging the distributions of energy *at a given instant* over the different systems, we wish to infer similar properties for the corresponding *time-averages* for any one of the systems.

It is easy enough to suggest systems to which the assumption is inapplicable. Most of the 'test cases' which have been suggested as disproving the law, and which will be considered later on, are instances of such systems. Lord Rayleigh[3] has suggested as another instance an elastic ball moving on a table having a circular boundary, at which it is reflected. If, instead of taking a single particle, Lord Rayleigh had supposed the table covered with such particles initially distributed uniformly over its area, and projected in such a manner that at any point as many particles were moving in one direction as in another, he would find these same conditions satisfied at any subsequent time, and this is, to my mind, all that Maxwell proves.

11. It is far less easy to suggest any simple system which *does* satisfy the assumption. The tracing point of a Lissajous' pendulum curve-tracer, considered by Boltzmann,[4] or in other words a particle whose equations of motion are

$$\dot{x}+a^2x=0, \qquad \ddot{y}+b^2y=0,$$

possesses when a, b are incommensurable the property of passing sooner or later through every point within a certain rectangle, but it does not possess the other necessary property of passing through any point in every possible direction in succession. This may be easily seen for the simplest case when a is nearly but not quite equal to b: here the path is nearly elliptical, and there are only two possible directions at any point. Hence, in order to satisfy the assumption, Boltzmann requires a thin elastic cylinder to be placed perpendicularly to the plane of motion, so that the particle may have its direction of motion changed each time it strikes and rebounds from the cylinder. And this introduces collisions into the problem.

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[1] 'Ueber die Eigenschaften monocyklischer und anderer damit verwandter Systeme,' *Journal für die reine und angewandte Mathematik*, xcviii. p. 68. 'Analogien des zweiten Hauptsatzes,' *ibid.*, c. pp. 206, 207, and other papers.

[2] *Kinetic Theory of Gases*, new edition, p. 23.

[3] *Phil. Mag.*, April 1892, p. 357.

[4] 'Ueber die mechanischen Analogien des zweiten Hauptsatzes der Thermodynamik,' *Journal für die Mathematik*, c. p. 203.

To discover, if possible, a general class of dynamical systems satisfying the assumption would form an interesting subject for future investigation. It is, however, doubtful how far Maxwell's law would be applicable to the *time-averages* of the energies in any such system. We shall see, in what follows, that the law of permanent distribution of a very large number of systems is in many cases not unique. Where there is more than one possible distribution it would be difficult to draw any inferences with regard to the average distribution (taken with respect to the time) for one system.

Thus the proof of Maxwell's Law of Partition of Energy furnishes no *general* conclusions with regard to the average distribution of energy in a *single conservative* dynamical system with a finite number of degrees of freedom, independently of initial circumstances, except by making assumptions which are nearly tantamount to assuming the law. It may reasonably be inferred that no such conclusions exist. We shall therefore assume in future, unless otherwise stated, that we are dealing with the distribution at any instant in a large number of systems.

12. It is probable that the molecules of a gas in the 'special' or equilibrium state, in consequence of their frequent collisions, satisfy the assumption, which Boltzmann[1] has employed to give a simple proof of the $e^{-h\mathrm{E}}$ law of distribution. But he was careful to point out that no proof had been given that the assumption either was satisfied or could be satisfied by gas-molecules, and he therefore referred for an alternative verification of his results to an independent but longer proof[2] based on a consideration of the collisions between molecules. Similar questions are raised by Boltzmann in his Appendix to this Report.

The Evaluation of the Functional Determinant.

13. Watson[3] has raised an objection to Maxwell's evaluation of the functional determinant on the ground that the result takes the form

$$\frac{\partial(p_1', \ldots q_n')}{\partial(p_1, \ldots q_n)} = \frac{\Delta}{\Delta'}$$

where Δ and Δ' are separately zero; and, therefore, the investigation leaves the value of the determinant undeterminate. This, he shows, follows from the fact that the condition E constant supplies no independent relation between the initial and final states.

Both Watson[4] and Lord Rayleigh[5] have therefore given an independent proof based on the substitution of Hamilton's 'principal function' S, for the 'action' A, where

$$\mathrm{S} = \int_t^{t'} (\mathrm{T} - \mathrm{V})\,dt$$

and

$$p_r' = \frac{d\mathrm{S}}{dq_r'}; \quad p_r = -\frac{d\mathrm{S}}{dq_r} \quad . \quad . \quad . \quad . \quad (7)$$

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[1] 'Einige allgemeine Sätze über Wärmegleichgewicht,' *Sitzungsberichte der k. Wiener Akademie der Wissenschaften*, lxiii. (part ii.), pp. 707, 711.

[2] 'Ueber das Wärmegleichgewicht zwischen mehratomigen Gasmolekülen,' *Sitzber. der k. Wiener Akad.*, lxiii. (ii.), p. 397.

[3] *Nature*, May 12, 1892; *Kinetic Theory of Gases*, new ed., p. 22, footnote.

[4] *Kinetic Theory of Gases*, § 8.

[5] *Phil. Mag.*, April 1892.

Whence they show that *if the motions all occupy a fixed time*, so that the initial and final states are connected by the assumed relation $t'-t=$constant, then

$$\frac{\partial(p_1', \ldots p_n', q_1', \ldots q_n')}{\partial(p_1, \ldots p_n, q_1, \ldots q_n)}=1 \quad . \quad . \quad . \quad (1)$$

14. There is another Jacobian relation similar in form but entirely different in meaning, of which the importance seems to have been hardly fully appreciated, if we may judge from the absence of references to it in most writings on the Kinetic Theory. In order that the Boltzmann-Maxwell Law may be *definite*, it must be independent of the choice of variables as co-ordinates of the systems considered, and for this it is necessary for the multiple differential

$$dp_1\,dp_2 \ldots dp_n\,dq_1\,dq_2 \ldots dq_n$$

to be independent of the particular co-ordinates $q_1, q_2, \ldots q_n$ chosen to specify the configuration of the system of each instant of time, provided that $p_1, p_2, \ldots p_n$ are the corresponding momenta.

The proposition may be stated and proved as follows :—

Let $q_1, q_2, \ldots q_n$ be any generalised co-ordinates defining a dynamical system, with n degrees of freedom ; $p_1, p_2, \ldots p_n$ the corresponding generalised momenta. Let $Q_1, Q_2, \ldots Q_n$ be any other set of co-ordinates, $P_1, P_2, \ldots P_n$ the corresponding momenta. It is required to prove that the relation

$$\frac{\partial(Q_1, Q_2, \ldots Q_n, P_1 \ldots P_n)}{\partial(q_1, q_2, \ldots q_n, p_1 \ldots p_n)}=1 \quad . \quad . \quad . \quad (8)$$

holds good at any instant of the motion.

Let the new co-ordinates be connected with the old by the relations

$$Q_1=f_1\,(q_1, q_2, \ldots q_n, t), \text{ \&c.}$$

Then by differentiation

$$\dot{Q}_1=\frac{\partial f_1}{\partial q_1}\dot{q}_1+\frac{\partial f_2}{\partial q_2}\dot{q}_2 + \ldots +\frac{\partial f_1}{\partial t}$$

$$=\frac{\partial Q_1}{\partial q_1}\dot{q}_1+\frac{\partial Q_2}{\partial q_2}\dot{q}_2+ \ldots +\frac{\partial f_1}{\partial t}$$

whence

$$\left(\frac{\partial \dot{Q}_m}{\partial \dot{q}_n}\right)_{t,\,q_1,\,q_2 \ldots q_n \text{ const.}}=\frac{\partial Q_m}{\partial q_n}.$$

Again, $\frac{\partial Q_m}{\partial p_n}=0$, since the equations of relation do not depend on the velocities or momenta.

From the last relations the terms in a quarter-square of the Jacobian vanish ; and, therefore, the Jacobian

$$=\frac{\partial(Q_1, \ldots Q_n)}{\partial(q_1, \ldots q_n)} \times \frac{\partial(P_1, \ldots P_n)}{\partial(p_1, \ldots p_n)}.$$

Now, supposing that $t, q_1, \ldots q_n$ are kept constant during differentiation, we have

$$P_1 = \frac{\partial T}{\partial \dot{Q}_1} = \frac{\partial T}{\partial \dot{q}_1}\frac{\partial \dot{q}_1}{\partial Q_1} + \frac{\partial T}{\partial \dot{q}_2}\frac{\partial \dot{q}_2}{\partial Q_2} + \ldots$$

$$= p_1\frac{\partial \dot{q}_1}{\partial \dot{Q}_1} + p_2\frac{\partial \dot{q}_2}{\partial \dot{Q}_1} + \ldots$$

$$\therefore \frac{\partial(P_1, P_2, \ldots P_n)}{\partial(p_1, p_2, \ldots p_n)} = \frac{\partial(\dot{q}_1, \dot{q}_2 \ldots q_n)}{\partial(\dot{Q}_1, \dot{Q}_2 \ldots \dot{Q}_n)} = \frac{\partial(q_1, q_2 \ldots q_n)}{\partial(Q_1, Q_2 \ldots Q_n)}$$

$$\therefore \frac{\partial(P_1, P_2, \ldots P_n)}{\partial(p_1, p_2, \ldots p_n)} \times \frac{\partial(Q_1, Q_2, \ldots Q_n)}{\partial(q_1, q_2, \ldots q_n)} = 1. \quad \text{Q.E.D.}$$

The Most General Law of Permanent Distribution for Non-colliding Systems.

15. The possible laws of permanent distribution of the co-ordinates and momenta among a large number of such systems may now be established thus:—

We know that for any one system the total energy is independent of the time or

$$E = \text{constant},$$

and the determinantal relation shows that the multiple differential

$$dp_1\, dp_2 \ldots dq_n$$

is also independent of the time.

Therefore, if the law of distribution be such that the number of systems included within the multiple differential at any instant of time (t) is

$$f(E)\, dp_1 \ldots dq_n \quad \ldots \ldots \quad (9)$$

where f denotes any function whatever, the same law will hold good at any subsequent instant of time (t').

16. The above proof depends only on the fact that E=constant is an integral of the equations of motion of the system and not on any other property peculiar to E. But the equations of motion may have other integrals as well. In such cases (3) does not represent the most general law of permanent distribution.

For if the integrals in question be

$$h_1 = \text{const.} \quad h_2 = \text{const.}, \text{ \&c.}$$

then *any* distribution expressed by the formula

$$f(E, h_1, h_2, \ldots .)\, dp_1 \ldots . dq_n \quad \ldots \quad (10)$$

will also be independent of the time, and therefore permanent.

This is the most general form of the law of permanent distribution in a system of non-colliding bodies. It is applicable in particular to the free systems considered in Part II. of Maxwell's paper, where $h_1, h_2 \ldots$ may denote the velocity components of the centre of gravity, and the component angular momenta about the centre of gravity.

17. Again, take the case of a number of particles distributed uniformly throughout infinite space and moving uniformly in straight lines under no

forces without ever colliding with one another. If u, v, w be the velocity components of any particle, these are constant throughout all time, and therefore the theorem asserts that *any* law of distribution of the form

$$f(u, v, w)\,du\,dv\,dw\,dx\,dy\,dz$$

is permanent; a conclusion which is obviously correct.

18. In Maxwell's paper f is to be taken constant for one particular value of E, and zero for all others.

In the Kinetic Theory of Gases f is proportional to $e^{-h\mathrm{E}}$.

The question as to how far this law is unique has been raised by Messrs. Watson and Burbury,[1] who quote Boltzmann's demonstration of the proposition, but admit that there may be exceptions to its truth. That demonstration is, however, based on a consideration of the collisions between the molecules of a gas, and has no application to a problem like the present, where all the systems considered are independent conservative systems, and no transference of energy takes place between the bodies of one system and those of the other. It will be considered fully in Section II. § 42.

19. Since for a conservative system E is always constant, there will always exist *possible* laws of permanent distribution, for which f is any function of E; but the possibility of other distributions will depend on the nature of the system and the existence of other integrals of the equations of motion.

The Reduction of the Kinetic Energy to a Sum of Squares.—Maxwell's Law of Partition of Energy.

20. Objections have been raised to this step in Maxwell's work by myself[2] on the ground that the kinetic energy cannot in general be expressed as the sum of squares of *generalised momenta* corresponding to generalised co-ordinates of the system, and by Lord Kelvin[3] on the ground that the conclusion to which it leads has no intelligible meaning. Boltzmann[4] has put the investigation into a slightly modified form which meets the first objection, and which imposes a certain restriction on the generality of the result. Under this limitation the result is perfectly intelligible, and the second objection is therefore also met.

21. Boltzmann reduces the kinetic energy to the form

$$\mathrm{T}=\tfrac{1}{2}\sum_{\iota=1}^{\iota=n}\mu_\iota a_\iota^2;$$

but he does not assume the quantities a_ι to be generalised momenta. He calls these quantities 'momentoids.' They are *linear* functions of the generalised momenta of the system, and calling these latter $p_1, p_2, \ldots$, the momentoids are supposed chosen so that the determinant

$$\Theta=\frac{\partial(a_1, a_2 \ldots a_n)}{\partial(p_1, p_2 \ldots p_n)}=1;$$

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[1] *Nature*, June 2, 1892, p. 101.

[2] *Report on Thermodynamics*, Part I. § 44.

[3] *Nature*, August 13, 1891.

[4] 'On the Equilibrium of Vis Viva,' Part III. *Phil. Mag.*, March 1893. The original is in the *Sitzungsberichte* of the Academy of Munich (not Vienna), and forms the third part to the author's 'Studien über das Gleichgewicht, &c.' (*Wiener Sitzb.*, lviii. (ii.), Oct. 1868), and his 'Weitere Studien' (*Wiener Sitzb.*, lxvi. (ii.), Oct. 1872).

an assumption which is convenient but not essential, because Θ can only be a function of the generalised co-ordinates, and the investigation applies only to systems *in a given configuration* for which these co-ordinates are therefore constant. Boltzmann supposes with Maxwell that the energy is the same for all the systems, and with these premises he proves that the mean value of each of the terms

$$\tfrac{1}{2}\,\mu_i a_i^2$$

has the same value. He concludes : 'Instead of the law of Maxwell that the mean vis viva has the same value for every co-ordinate, we now obtain the law that the mean value of the vis viva belonging to all *momentoids* is the same.'

From this Boltzmann concludes that 'the mean kinetic energies of two given parts of the system are in the ratio of their respective degrees of freedom,' *provided that the kinetic energy contains no products of a generalised momentum of one of the given parts into a generalised momentum not belonging to that part.*

22. Now in Appendix A I have shown that for non-colliding rigid bodies laws of permanent distribution exist in which the mean kinetic energies due to the rotations about the three principal axes are *unequal.* This test case shows, therefore, that Maxwell's result is not always true for *every* possible law of distribution. The following method is shorter than Boltzmann's and Maxwell's, and shows under what circumstances the mean kinetic energies belonging to the momentoids may be unequal.

Let the law of distribution be given by the formula (9),

$$f(\mathrm{E})\,dp_1 \;\ldots\; dp_n\,dq_1 \;\ldots\; dq_n,$$

and let $k_1, k_2, \ldots k_n$ be n linear functions of $p_1, p_2, \ldots p_n$, such that the kinetic energy is of the form

$$\mathrm{T}=\tfrac{1}{2}\,(k_1^2+k_2^2+ \;\ldots\; k_n^2) \quad . \quad . \quad . \quad (11)$$

Then, since these functions are linear, the determinant

$$\Theta=\frac{\partial\,(k_1, k_2 \;\ldots\; k_n}{\partial\,(p_1, p_2 \;\ldots\; p_n)}$$

is a function of the co-ordinates $q_1, \ldots q_n$ alone, and since we are dealing only with those systems which happen to be in a given configuration at the instant considered, Θ is constant, the potential energy V is constant, and so is the multiple differential $dq_1 \ldots dq_n$. The mean value of $\frac{1}{2}k_r^2$ for these systems is therefore

$$\tfrac{1}{2}\overline{k_r^2}=\frac{\int_{-\infty}^{\infty} f\{\tfrac{1}{2}(k_1^2+k_2^2+ \;\ldots\; k_n^2)+\mathrm{V}\}\,\tfrac{1}{2}k_r^2 dp_1 \;\ldots\; dp_n}{\int_{-\infty}^{\infty} f\{\tfrac{1}{2}(k_1^2+k_2^2+ \;\ldots\; k_n^2)+\mathrm{V}\}\,dp_1 \;\ldots\ldots\; dp_n}$$

$$=\frac{\int_{-\infty}^{\infty} f\{\tfrac{1}{2}(k_1^2+ \ldots +k_n^2)+\mathrm{V}\}\,\tfrac{1}{2}k_r^2 dk_1 \;\ldots\; dk_n}{\int_{-\infty}^{\infty} f\{\tfrac{1}{2}(k_1^2+ \ldots +k_n^2)+\mathrm{V}\}\,dk_1 \;\ldots\ldots\; dk_n};$$

and this is obviously the same for all the co-ordinates k_r, thus

$$\tfrac{1}{2}\overline{k_1^2}=\tfrac{1}{2}\overline{k_2^2}=\ \ldots\ =\tfrac{1}{2}\overline{k_n^2}\ .\quad .\quad .\qquad (12)$$

Also by addition

$$\tfrac{1}{2}\overline{k_1^2}+\tfrac{1}{2}\overline{k_2^2}+\ \ldots\ =\overline{\mathrm{T}}\,;$$

therefore each of the above mean values is one nth of the mean value of T.

If there exist other possible permanent distributions given by (10) for which the function f involves other integrals of the equations of motion besides the energy, the argument will still hold good *provided these integrals only involve the co-ordinates of the system, and not its velocities or momenta,* because these co-ordinates are kept constant during integration. Such integrals may, for example, depend on the equations of the paths of the particles forming the system.

But if f involves any function of the *momenta* or *velocities* other than the energy, the integral in the numerator will assume different forms for different k's, and the mean values of the different squares forming the kinetic energy will, *in general*, be unequal.

I would propose that the name MAXWELL'S LAW OF PARTITION OF KINETIC ENERGY be in future applied exclusively to the statement that if the kinetic energy of a given system be expressed as a sum of squares, the mean values of these several squares taken over a large number of systems distributed in a given manner are equal.

Hence Maxwell's Law of Partition of Kinetic Energy is only true under the conditions stated above.

Test Cases of the Law.—Motion of a Particle in a Plane.

23. The test cases suggested by Lord Kelvin as apparently contradicting Maxwell's Law of partition will be found, on examination, to afford a valuable confirmation of all that has been said above regarding the restrictions to which the law is subject.

It is rather remarkable that the motion of a particle in a plane has been employed by Boltzmann[1] to furnish an illustration of the law, and by Lord Kelvin[2] to furnish an apparent contradiction of it, which has, however, since been met by Boltzmann.[3]

Lord Kelvin shows that it is impossible to give a general proof that for a *single particle* moving in a plane the *time-averages* of $\dot{x}^2$ and $\dot{y}^2$ are equal. This confirms what has been said in §§ 10–12 as to the impossibility of applying Maxwell's law of partition to a single conservative dynamical system. If, instead of a single particle, Lord Kelvin had covered the plane with particles, and had projected them so that their co-ordinates and velocities initially satisfied any law of distribution given by the formula

$$f(\mathrm{E})\, dx\, dy\, du\, dv,$$

he would have found the same law to be satisfied at any subsequent time, and the average values of u^2 and v^2 to be equal.

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[1] 'Einige allgemeine Satze über Wärmegleichgewicht,' *Sitzb. der k. Wiener Akad.*' lxiii. (ii.) (1871), p. 700.
'Lösung eines mechanischen Problems,' *ibid.*, lviii. (ii.)

[2] *Nature*, August 13, 1891.

[3] *Phil. Mag.*, March 1893. See footnote to § 20 above.

24. To prove this, Boltzmann has given (*loc. cit.*) a highly artificial and laborious verification of the Jacobian relation

$$\frac{\partial(x', y', \theta')}{\partial(x, y, \theta)}=1 \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where θ is the angle the direction of motion makes with the axis of x, and θ' its value after a time t', which Boltzmann takes to be a small interval, δt. As Boltzmann's proof is not easy to follow, it may be interesting to obtain the same result much more simply and without imposing restrictions on the magnitude of the time-interval t' by considering the Jacobian

$$\Delta=\frac{\partial(x', y', u', v')}{\partial(x, y, u, v)}=\frac{\partial(x', y', \dot{x}', \dot{y}')}{\partial(x, y, \dot{x}, \dot{y})}.$$

We have, keeping the initial time constant,

$$\frac{d\Delta}{dt'}=\frac{\partial(\dot{x}', y', \dot{x}', \dot{y}')}{\partial(x, y, \dot{x}, \dot{y})}+\frac{\partial(x', \dot{y}', \dot{x}', \dot{y}')}{\partial(x, y, \dot{x}, \dot{y})}+\frac{\partial(x', y', \ddot{x}', \dot{y}')}{\partial(x, y, \dot{x}, \dot{y})}+\frac{\partial(x', y', \dot{x}', \ddot{y}')}{\partial(x, y, \dot{x}, \dot{y})}.$$

The first two Jacobians evidently vanish. And by the equations of motion

$$\ddot{x}'=-\frac{\partial \mathrm{V}'}{\partial x'}; \qquad \ddot{y}'=-\frac{\partial \mathrm{V}'}{\partial y'}.$$

Hence $\ddot{x}'$, $\ddot{y}'$ are functions of x', y', and the quantities in the numerators of the last two Jacobians are not all independent : therefore these vanish. Therefore integrating with respect to t' :

$$\Delta=\text{constant}=1, \text{(its initial value)} \quad . \quad . \quad . \quad (14)$$

If

$$q^2=u^2+v^2, \tan\theta=v/u$$

we have by the transformation from Cartesian to polar co-ordinates

$$\Delta=\frac{\partial(x', y', \tfrac{1}{2}q'^2, \theta')}{\partial(x, y, \tfrac{1}{2}q^2, \theta)}.$$

In virtue of the equations of energy

$$\tfrac{1}{2}q'^2=\mathrm{E}-\mathrm{V}', \quad \tfrac{1}{2}q^2=\mathrm{E}-\mathrm{V}$$

$$\frac{\partial(\tfrac{1}{2}q'^2)}{\partial \mathrm{E}}=1=\frac{\partial(\tfrac{1}{2}q^2)}{\partial \mathrm{E}}$$

$$\Delta=\frac{\partial(x', y', \theta', \mathrm{E})}{\partial(x, y, \theta, \mathrm{E})}=\frac{\partial(x', y', \theta')}{\partial(x, y, \theta)}$$

whence (13)

$$\frac{\partial(x', y', \theta')}{\partial(x, y, \theta)}=1$$

as was to be proved.

25. And assuming the law of distribution

$$f(\mathrm{E})\, dx\, dy\, du\, dv \quad . \quad . \quad . \quad . \quad . \quad (15)$$

we have evidently

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\tfrac{1}{2}u^2+\tfrac{1}{2}v^2+\mathrm{V})\,u^2 du dv=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(\tfrac{1}{2}u^2+\tfrac{1}{2}v^2+\mathrm{V})\,v^2 dv du,$$

and therefore

$$\text{average value of } u^2 = \text{average value of } v^2 \quad . \quad . \quad . \quad (16)$$

in accordance with Maxwell's Law. The same thing would also be true if, the equations of the orbits of the particles being

$$\phi(x, y) = \text{constant},$$

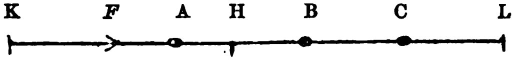
f were a function of ϕ as well as of E, or indeed of any integral of the equations of motion other than E, involving *co-ordinates only* and *not velocities.*

Lord Kelvin's 'Decisive Test Case.'

26. The test case by which Lord Kelvin claims to have 'effectually disposed of' Maxwell's law of partition [1] really confirms all that has been said about the law in this Report. It shows the impossibility of drawing general conclusions as to the distribution of energy in a *single* system from the possible law of permanent distribution in a large number of systems. In other words, it tells us once more that the mean value of any portion of the energy obtained by integrating with respect to the multiple differential of the co-ordinates and momenta is not necessarily equal to the mean value obtained by integrating with respect to the time for a *single* system.

This test case has been criticised in a general sort of way by Mr. E. P. Culverwell,[2] and the following investigation will, I think, accord with his views :—

27. The equal masses A and C are supposed to be separated by a 'simple vibrator' B with which they can collide, and Lord Kelvin assumes that in the course of a large number of collisions this vibrator will equalise and keep equal the average kinetic energies with which A and C rebound from B. C is reflected by a fixed wall at L; but A, in addition to being stopped by a fixed reflecting wall at K, is acted on by a repulsive force from K while it lies within a certain space, KH. Part of the energy with which A left B then becomes potential while the energy of C always remains kinetic, and Lord Kelvin infers that the average kinetic energy of A is less than that of C.



Now it is not obvious that the vibrator at B will actually always equalise the average kinetic energies of rebound of A and C. If KB is much greater than BL, C will collide with B much more frequently than A, and I should be inclined to think that without investigation no definite relation could be assumed between the average energies of rebound of A and C. But this is quite irrelevant to the point. Accordingly, let us assume the vibrator to be possessed of the property in question, so that the average energies of A and C are equal. Let x, x' be the co-ordinates of A and C, u, u' their velocities, χ the potential energy of A, so that χ vanishes when A is outside the region KH. Take each particle of unit mass.

Then the law of distribution *as stated and proved in this Report* asserts that if there are a very large number of systems exactly like the one described, and if the proportion of these systems in any given phase is measured by an expression of the form

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[1] *Phil. Mag.*, May 1892, p. 466; *Nature*, May 5, 1892. p. 21.

[2] *Nature*, May 26, 1892, p. 76.

$$f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2)\,du\,du'\,dx\,dx' \quad . \quad . \quad . \quad (17)$$

the same law of distribution will hold good at any subsequent time. Also the mean kinetic energies with which the two particles pass simultaneously through two given configurations are

$$\frac{\iint f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2)\,\tfrac{1}{2}u^2du\,du'}{\iint f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2)\,du\,du'} \text{ and } \frac{\iint f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2)\,\tfrac{1}{2}u'^2du\,du'}{\iint f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2)\,du\,du'},$$

and are therefore equal.

28. The test case derives an additional interest because it forms a sort of transition between those systems in which the form of f is indeterminate and the systems of colliding bodies with which we have to deal in the Kinetic Theory of Gases where $f=e^{-hE}$.

For in general (17) will represent a law according to which the distribution of the A particles depends on the energies of the corresponding C particles in the systems to which they belong. If, however, the distribution of the A particles is independent of that of the C particles, their separate laws of distribution being

$$f_A du\,dx \text{ and } f_C du'\,dx',$$

then we must have

$$f_A \times f_C = f(\chi+\tfrac{1}{2}u^2+\tfrac{1}{2}u'^2),$$

the most general solution of which assumes the well-known form

$$f_A=e^{-h(\chi+\frac{1}{2}u^2)} \qquad f_C=e^{-h\,.\,\frac{1}{2}u'^2} \quad . \quad . \quad . \quad . \quad (18)$$

h being any constant whatever. In that case the mean kinetic energy of all the A's in the neighbourhood of a given point *irrespective* of the corresponding position of the C's is

$$=\frac{\int_{-\infty}^{\infty} e^{-h\,.\,\frac{1}{2}u^2}(\tfrac{1}{2}u^2)\,du}{\int_{-\infty}^{\infty} e^{-h\,.\,\frac{1}{2}u^2}du}=\frac{1}{2h} \quad . \quad . \quad . \quad (19)$$

as in the Kinetic Theory of Gases. This accords exactly with the remarks of Mr. Culverwell already mentioned. The A's do not all reach K every time, those that are moving slowly only penetrating a small distance into the region KH, and the depth of penetration increasing with the velocity at H or B. Hence the *density* of distribution of the A's diminishes as we approach K, but out of the whole number at any point the *proportion* having kinetic energies within certain limits will be the same everywhere.

Summary.

29. The conclusions so far arrived at may be summed up as follows :—

(i) If there exist a very (infinitely) great number of independent conservative dynamical systems, the equations of motion of each system having in addition to the equation of energy, any number of integrals h_1=const., h_2=const., &c., and if at any given instant the systems are so distributed that the number of them whose co-ordinates and momenta lie within given small limits is proportional to *any function whatever* of E, h_1, h_2 . . ., then the distribution will be permanent, the systems being similarly distributed at every subsequent instant of time.

(ii) If the kinetic energy be expressed as the sum of squares, and if the frequency-function involves no integrals of the equations of motion containing velocities or momenta with the exception of the energy, then the mean values of the different squares are all equal to one another. [*Maxwell's Law of Partition of Kinetic Energy.*]

SECTION II.—SYSTEMS OF COLLIDING MOLECULES.

Applicability of the Preceding Investigations to Gases.

30. Before considering in detail those investigations in which collisions and encounters between the molecules of a gas are taken specially into account, it may be well to examine briefly how far the general results established in Section I. can be applied to the problem of the Kinetic Theory of Gases (see also Boltzmann's Appendix, *infra*).

The 'independent systems' considered above may be chosen in several different ways.

(i) We may take each 'system' to represent a single molecule of gas moving about freely or in a field of external force. The above investigations will apply so long as the molecules considered do not encounter or collide with other molecules, and we conclude that in the absence of such encounters any distribution determined by the expression (14) of § 15 will be permanent if the $2n$ quantities p_1, . . . q_n represent the n momenta and n co-ordinates of a single molecule.

This is most important. It is not sufficient in the Kinetic Theory to investigate a law of distribution which is unaffected by collisions or encounters any more than it is sufficient to investigate a law which is permanent in their absence. It is necessary to satisfy conditions of permanence in both cases.

(ii) We may take each 'system' to represent a pair of molecules or a group of several molecules in the course of a binary or multiple encounter, it being assumed that the intermolecular forces remain finite during encounter, and that at each instant there are sufficient encounters of the same kind to give rise to a law of permanent distribution among the encountering sets of molecules. Here the quantities q_1, . . . q_n will have to include all the co-ordinates of all the molecules in the group considered. Then any distribution determined by (8) will be permanent so long as the molecules of any one group do not encounter any molecules not in that group.

But in a gas each molecule will encounter various molecules in succession, so that the same set of molecules cannot be considered permanently as a system apart from the rest. From this we find at once that *if the frequency of distribution* f *is a function of the energy alone*[1] it must be of the well-known form

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[1] This is not the case if the mass of gas has a perceptible motion of translation or rotation (see § 45 and Appendix B).

$$e^{-hE}.$$

For *before* two molecules encounter each other the frequency of distribution of the co-ordinates and momenta of one cannot depend on the co-ordinates and momenta of the other. Hence if f_1, f_2 denote the frequencies of distribution of the two molecules just before the encounter

$$f_1 \times f_2 = f(E).$$

Now the same law must hold just before the encounter as during it, and just before the encounter the *mutual* potential energy of the molecules is zero, so that

$$E = E_1 + E_2,$$

where $E_1 E_2$ are the separate energies of the molecules; and the resulting relation

$$f_1 \times f_2 = f(E_1 + E_2) \quad . \quad . \quad . \quad . \quad (20)$$

can only be satisfied by

$$f_1 = e^{-hE_1} \quad f_2 = e^{-hE_2}.$$

Hence before and after the encounter the molecules have their co-ordinates and momenta distributed with frequencies proportional to e^{-hE_1} and e^{-hE_2} respectively. But *during* an encounter the frequency of distribution of *all* the co-ordinates and momenta of the pair or group is proportional to e^{-hE}.

For a pair of molecules we may write the function

$$\begin{aligned} f &= e^{-h(T_1+\chi_1+T_2+\chi_2+\chi_{12})} \\ &= e^{-hT_1} \times e^{-hT_2} \times e^{-h(\chi_1+\chi_2+\chi_{12})} \quad . \quad . \quad . \quad (21) \end{aligned}$$

where χ_1 χ_2 are the potential energies of the molecules due to the field, χ_{12} their mutual potential energy. This shows that for any given *configuration* the *momenta* of the molecules denoted by the suffixes 1, 2 are separately distributed with frequencies proportional to e^{-hT_1} and e^{-hT_2} respectively. The distribution of the *co-ordinates* of one molecule is not, however, independent of the position of the other owing to the presence of the factor $e^{-h\chi_{12}}$. When the encounter is over χ_{12} vanishes, so that this factor disappears, and the distributions of the co-ordinates of the two molecules become independent of each other.

Similar reasoning holds good for encounters involving any number of molecules provided that these encounters are sufficiently frequent to *have* a law of distribution.

(iii) If either the molecules act on each other *at all distances*, or they cannot be divided into independent isolated groups, a 'system' must be taken to represent nothing short of the whole mass of gas—or other matter—under consideration. We therefore require the distribution in a single system, and this brings us face to face with the difficulties considered in §§ 10–12. Maxwell certainly contemplated the applicability of his investigation to cases of this kind (see § 3); but the assumption required for this generalisation is at variance with the inferences drawn from the test cases of §§ 23–28, whatever may otherwise be said in its favour.

The Functional Determinants for Encounters and Collisions.

31. The reasoning of Case II. of the last article cannot be regarded as conclusive without further investigation if the forces of encounter become impulsive as in the case of a collision. For Watson [1] has pointed out that the determinantal relation (1)

$$\frac{\partial(p_1', \ldots q_n')}{\partial(p_1, \ldots q_n)}=1,$$

with the total time t constant is inapplicable, and, moreover, the S function used in proving it becomes discontinuous in the case of impacts.

The difficulty can be overcome by regarding impulsive forces as the limit of finite forces, and supposing the initial and final states separated by a small constant interval of time during which the impact occurs; but it is certainly highly desirable to treat the problem separately.

32. According to Watson, the objections will be avoided if, instead of supposing the time constant, we assume the initial and final states to be connected by a geometrical relation between the co-ordinates which can be expressed in the form

$$q_n-q_n'=C,$$

and that in that case the functional Jacobian

$$\frac{\partial(p_1, \ldots q_{n-1})}{\partial(p_1', \ldots q_{n-1}')}=-\frac{\dot{q}_n'}{\dot{q}_n} \quad . \quad . \quad . \quad (22)$$

This relation is verified by Watson for the case of a projectile in his letter in 'Nature.' But in his 'Kinetic Theory of Gases' [2] he derives it from the relation (1) with t constant, so that his method applies only to finite forces.

If, however, in the course of an encounter between molecules, impulsive action takes place owing to the energy-function changing discontinuously when the geometrical relation

$$q_n=c$$

is satisfied, we will now show that the states before and after the impulse are connected by the relation

$$\frac{\partial(p_1', \ldots p_n', q_1' \ldots q_{n-1}')}{\partial(p_1, \ldots p_n, q_1 \ldots q_{n-1})}=+\frac{\dot{q}_n}{\dot{q}_n'} \quad . \quad . \quad . \quad (23)$$

provided that the principle of Conservation of Energy is satisfied.

For if λ be the instantaneous increase of potential energy when q_n passes through the value c, then the initial and final kinetic energies satisfy the relation

$$T-T'=\lambda \quad . \quad . \quad . \quad . \quad . \quad (24)$$

where λ may be a function of $q_1 \ldots q_{n-1}$.

Now since no impulsive action takes place through the variation of the co-ordinates $q_1 \ldots q_{n-1}$ we have

$$p_1'=p_1, p_2'=p_2, \ldots p_{n-1}'=p_{n-1},$$

and therefore

$$dp_1'=dp_1, dp_2'=dp_2, \ldots dp_{n-1}'=dp_{n-1}.$$

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[1] *Nature*, May 12, 1892, p. 29.

[2] *Kinetic Theory of Gases*, p. 37.

Hence the remaining differentials are connected by the relation

$$\frac{\partial T}{\partial p_n} dp_n - \frac{\partial T'}{\partial p_n'} dp'_n = 0 ;$$

i.e.,

$$-\dot{q}_n dp_n + \dot{q}_n' dp'_n = 0 ;$$

or

$$\frac{dp_n'}{dp_n} = \frac{\dot{q}_n}{\dot{q}_n'} .$$

Moreover, since the impulsive action takes place instantaneously, the co-ordinates do not vary, and therefore

$$dq_1' = dq_1,\ dq_2' = dq_2\ \ldots\ dq_{n-1}' = dq_{n-1} ;$$

$$\therefore \frac{dp_1' \ldots dp_n'\, dq_1' \ldots dq_{n-1}'}{dp_1 \ldots dp_n\, dq_1 \ldots dq_{n-1}} = \frac{\dot{q}_n}{\dot{q}_n'} . \quad \text{Q.E.D.}$$

This form of the Jacobian is applicable to the hypothetic law of molecular force, often assumed in the Kinetic Theory, where, when two molecules (regarded as material points) reach a certain distance, c, their mutual attraction becomes infinite. Their directions of motion undergo refraction towards the line joining them at the beginning of the encounter and away from that line at the end of the encounter, and each refraction must be treated separately, Watson's relation (22) being used for the motion of the molecules between the two refractions.

33. In the case of a collision unaccompanied by loss of kinetic energy, such as occurs between perfectly smooth elastic bodies, the Jacobian relation between the velocities or momenta just before and just after the collision is easily found. For Burbury has shown[1] that in a system or pair of colliding systems with n degrees of freedom, $n-1$ linear functions of the velocities, which he calls $S_1, S_2, \ldots S_{n-1}$, are unaltered by the collision, and one linear function R has its sign changed. Therefore,

$$dS_1'\, dS_2' \ldots dS'_{n-1}\, dR' = -dS_1\, dS_2 \ldots dS_{n-1}\, dR,$$

and by the properties of Jacobians it follows at once that, since the co-ordinates of the system are unaltered, the initial and final momenta, specified by any co-ordinates whatever, are connected by the relation

$$\frac{\partial(p_1', p_2', \ldots p_n')}{\partial(p_1, p_2, \ldots p_n)} = -1 \quad . \quad . \quad . \quad . \quad (25)$$

In a collision between smooth bodies, R is the relative velocity of the points which come into contact resolved along the common normal, and Burbury has given examples of the functions $S_1, \ldots S_{n-1}$, R in several simple cases, viz., a pair of unequal smooth spheres, a sphere colliding with a spheroid, and a system of two spheres loaded at one side of their centres.

The same argument could probably be extended to multiple collisions, for if $n-r$ linear functions of the velocities were unaltered and the remaining r had their signs changed, the functional determinant would be equal to $(-1)^r$. Again, for a collision between two 'perfectly rough bodies' with a coefficient of 'frictional restitution' equal to unity the *three* components of the relative velocity of the points of contact would be reversed, so that r have the value 3.

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[1] 'On the Collision of Elastic Bodies,' *Phil. Trans. R.S.*, 1892, A, p. 408.

Statement of the Boltzmann-Maxwell Law.

34. It is highly desirable that some definite understanding should be agreed on as to what precisely constitutes the Boltzmann-Maxwell Law. I would suggest therefore—

(i) That the distribution of a large number of molecules or other dynamical systems of the same or different kinds in which the co-ordinates (q) and momenta (p) of each system are so arranged that the number of systems in the neighbourhood of any given state is proportional to

$$e^{-hE}dp_1 \dots dp_n dq_1 \dots dq_n \quad . \quad . \quad . \quad (26)$$

h being the same for all the kinds of molecules or systems, be called THE BOLTZMANN-MAXWELL DISTRIBUTION.

(ii) That the law which asserts the permanency of the Boltzmann-Maxwell distribution in any particular case be called THE BOLTZMANN-MAXWELL LAW.

(iii) That in future these names be not applied to any corollaries such as that which asserts the equality of the average value of the squares into which the kinetic energy can be split up. That corollary I have called *Maxwell's Law of Partition of Kinetic Energy.*

I trust that the adoption of these names will be of assistance in securing that uniformity of nomenclature which is always so desirable in all branches of science.

Verification for Particular Cases.—Spheres and Circles.

35. It is not necessary to consider in detail the law of distribution in smooth colliding spheres whose centres of mass are at their centres of figure or, what is the same thing, material particles which rebound when they approach within a certain distance of one another. The truth of Avogadro's law, according to which the mean translational kinetic energies of the molecules of two mixed gases are equal, is now universally admitted. Even Tait does not deny it, but contents himself with maintaining that the law cannot be established without making certain assumptions, and these assumptions are discussed at great length by Boltzmann,[1] who, however, places more implicit confidence in Maxwell than is warranted by Section I. of this Report. It seems to me that Tait's three assumptions,[2] which are quoted in my first Report,[3] actually require little beyond the assumption that there *is* a law of permanent distribution. At any rate, this is all that is necessary for showing that Avogadro's law is a *possible* permanent law. The question as to how far the general law of distribution is unique can be much better discussed in connection with other applications (see § 45 below).

36. The next cases are those of spheres in which the C.M. is at a small distance from the centre of figure, *i.e.*, having a 'bias' as in the game of

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[1] 'Ueber die zum theoretischen Beweise des Avogadro'schen Gesetzes beforderlichen Voraussetzungen,' *Sitzber. der k. Wiener Akad.*, xciv. (ii.), Oct. 1886.

[2] 'On the Foundations of the Kinetic Theory of Gases,' *Trans. R.S.E.*, vol. xxxiii. Part I. (1886), p. 77.

[3] *Cardiff Report,* 1891, § 41, p. 113.

bowls, and the two-dimensional problem of circles in a plane having the same property. Both these cases have been fully investigated by means of long and complicated integrations by Boltzmann,[1] who has also extended his treatment to bodies of any shape, provided they are convex outwards and have no sharp corners.

The case of circular discs is also worked out fully by Watson,[2] who, however, takes the trouble of evaluating the functional determinant step by step by expressing the final in terms of the initial velocities; a process which is obviated by the method of § 33 above. The frequency of collisions of any kind is proportional to the relative velocity of the points of contact in that kind of collision. It is found that the condition of permanence will be satisfied if the number of discs whose three velocity components lie within the multiple differential $du\,dv\,d\omega$ is proportional to

$$Ne^{-hT}du\,dv\,d\omega \text{ or } N\exp-\tfrac{1}{2}hM(u^2+v^2+k^2\omega^2)\,.\,du\,dv\,d\omega \quad . \quad (27)$$

whether the discs in collision are similar or belong to two different sets. This is the Boltzmann-Maxwell Law.

37. The case of lop-sided spheres formed the subject of a faulty demonstration by Burnside, the result of which—quoted in my first Report, § 44, third to twelfth line—was in contradiction to the Boltzmann-Maxwell Law, and is now known to be incorrect. This has been shown by Watson,[3] by Burbury,[4] and also in his aforementioned paper by Boltzmann. The correct result is that if the velocities and angular velocities about the principal axes be arranged according to the Boltzmann-Maxwell distribution

$$Ne^{-hT}du\,dv\,dw\,d\omega_1\,d\omega_2\,d\omega_3\,. \quad . \quad . \quad . \quad (28)$$

that is

$$N\exp-\tfrac{1}{2}h\{M(u^2+v^2+w^2)+A\omega_1{}^2+B\omega_2{}^2+C\omega_3{}^2\}\;.\,du\,dv\,dw\,d\omega_1\,d\omega_2\,d\omega_3$$

this distribution will be unaffected by collisions. From Appendix A we see that it will also be unaffected by the free motion of the spheres between collisions, and therefore it satisfies all the necessary conditions of permanence. The mean values of Mu^2, Mv^2, Mw^2, $A\omega_1{}^2$, $B\omega_2{}^2$, $C\omega_3{}^2$, are equal. The other distribution of Appendix A, in which the mean kinetic energies due to the three principal rotations are unequal, is, in general, no longer permanent when collisions take place. In fact, Boltzmann starts by assuming a distribution of the form

$$N\frac{\sqrt{h^3.k_1k_2k_3}}{\pi^3}\exp-h\{u^2+v^2+w^2\}-k_1\omega_1{}^2-k_2\omega_2{}^2-k_3\omega_3{}^2\,.\,du\,.\,.\,.\,d\omega_3$$

and deduces that

$$h=\frac{k_1}{A}=\frac{k_2}{B}=\frac{k_3}{C}.$$

Now evidently this conclusion does not necessarily hold good if each molecule is symmetrical about the line joining its centres of inertia and of figure, because the angular velocity about this line will be unaffected both by collisions and by the free motion of the molecules. This angular velocity might, therefore, follow any law of distribution whatever, and that law would be permanent. Neither does the conclusion hold good if the centres of mass and of figure coincide.

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[1] 'Ueber das Gleichgewicht der lebendigen Kraft zwischen progressiver und Rotations-Bewegung bei Gasmolekülen,' *Sitz. d. k. Akad. zu Berlin*, Dec. 1888.

[2] *Kinetic Theory of Gases*, p. 15.

[3] *Nature*, vol. xlv. March 31, 1892, p. 512.

[4] *Ibid.*, vol. xlv. April 7. 1892, p. 533.

The arguments of Boltzmann might have been rather more conclusive if they had shown at *what* stage of the process these exceptional cases had to be excluded. Burnside did worse than this, for he said: 'Hence the three equations' (now known to be wrong) 'are *a* solution; and, therefore, must be *the* solution of the problem of the special state.'

The cases of *perfectly rough* spheres or circular discs having both their normal and tangential coefficients of restitution unity furnish interesting examples for solution. We may imagine the spheres and discs covered over with perfectly elastic fine teeth, or minute projections by whose action the tangential components of the relative velocity are reversed at impact, and it is no longer necessary to suppose the molecules to have a 'bias' in order to have a transference of energy between the translational and rotational kinds.

The Functional Equation for Colliding Bodies in General.

38. The earliest investigation of the law of distribution for molecules other than point-atoms (or smooth hard spheres, whose centres of mass and figure coincide) seems to be that of Boltzmann in 1871.[1]

At the present time the simplest and best treatment of the general problem for colliding bodies with any number of degrees of freedom is that given in Burbury's paper 'On the Collisions of Elastic Bodies.'[2] The methods there used are perfectly general, and include Watson's proofs for lop-sided circles and spheres as particular cases without the attendant complications in the formulæ, which arise from writing down in full the special forms of the various expressions assumed in those investigations.

39. The assumptions involved in proving the Boltzmann-Maxwell Law for colliding bodies seem to me to resolve themselves into the following:—

(i) That the law is *not meaningless.* The expression (26) or

$$Ne^{-h(T+\chi)}\,dp_1\,.\,.\,.\,dp_n\,dq_1\,.\,.\,.\,dq_n \qquad . \qquad . \qquad (29)$$

must represent a definite number of molecules.

Hence in a volume element so small that χ may be considered constant over it, there must be a very large number of molecules moving about with all possible momenta, and out of these a large number must have their remaining co-ordinates and momenta distributed within the corresponding small multiple differential. The law will obviously not hold at points where χ, the potential of the field, becomes infinite or discontinuous. Moreover, the collisions must be sufficiently frequent to admit of a similar law being applicable to the colliding molecules.

(ii) That any molecule has a chance of colliding with any other molecule. Hence the frequency of distribution of the molecules must depend on their actual state, and not on their past history or future prospects of colliding with any particular set of other molecules. As Burbury has just written in a letter to me: 'To take conventional elastic spheres as the simplest case we always assume as fundamental that if $f(a)$ denotes the chance of sphere A having velocity a, and $f(b)$ the chance of sphere B having velocity b, then *the chances are always independent*, whether A and B collide or not.'

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[1] 'Ueber das Wärmegleichgewicht zwischen mehratomigen Gasmolekülen,' *Sitzber. der k. Wiener Akad.*, lxiii. (ii.), p. 397.

[2] *Phil. Trans. R.S.*, 1892, pp. 407–422.

(iii) The demonstration is based on the hypothesis that in the permanent distribution the collisions of any one particular kind are balanced by an equal number of the opposite kind in which the initial and final states are simply reversed, so that the change in distribution produced by the former is exactly balanced by the latter. In other words, 'the numbers of direct and reverse collisions are equal.' This is obviously a *sufficient* if not a *necessary* condition of permanency.

40. From this it follows that if f, F denote the frequency function of distribution for two bodies, $p_1, \ldots p_n$ and $P_1, \ldots P_n$ their velocities or momenta, and accented letters refer to the state after collision, then, remembering that the frequency of collisions is proportional to R, the relative velocity of the point of contact, we have

$$Ff R\, dp_1 \ldots dp_n\, dP_1 \ldots dP_n = F'f' R'\, dp_1' \ldots dp_n'\, dP_1' \ldots dP_n'$$

Remembering that $R' = -R$ and applying (25) we have

$$Ff = F'f' \quad . \quad . \quad . \quad . \quad . \quad (30)$$

This is the functional equation that must be satisfied if the distributions determined by the functions F, f are to be unaltered by collision between the two sets of bodies to which they apply, and a similar condition must hold for collisions between bodies of the *same* kind. In this investigation, since the forces of collision are impulsive, the *co-ordinates* of the bodies are unaltered by collision, and do not enter into the multiple differentials, and for the same reason $p_1, \ldots P_n$ may be either generalised momenta or generalised velocities or linear functions of them sufficient to specify the motions of the colliding bodies.

I think that it could be similarly proved that for collisions each involving *three* bodies the functional equations would be of the form

$$f_1 f_2 f_3 = f_1' f_2' f_3'$$

provided, of course, that such collisions were numerous enough to *have* a law of distribution.

41. Natanson[1] has deduced the functional equation (30), which in his notation becomes

$$n_h n_k = n_r n_s \quad . \quad . \quad . \quad . \quad . \quad (31)$$

from the law of Gibbs relating to the chemical equilibrium in gas mixtures, assuming for the thermodynamical potential of the temperature and pressure the form

$$\Phi = \sum_j \mu_j n_j \phi_j \quad . \quad . \quad . \quad . \quad . \quad (32)$$

where

$$\phi_j = \zeta_j - \frac{RT}{\mu_j} \log \left(\frac{N}{n_j}\right) \quad . \quad . \quad . \quad (33)$$

Here m denotes the mass of any one of the gases, n_j the number of molecules, μ_j the mass of a molecule (so that $m_j = \mu_j n_j$), ζ_j a function of T and P, but not of n_j, and R a constant. The investigation is instructive and suggestive; unfortunately, however, the method of demonstration does not appear to be 'perfectly reversible,' but it is much to be hoped that Natanson will succeed in solving the converse problem of deducing (32), (33) from (31).

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[1] L. Natanson, 'Thermodynamische Deutung des Maxwell'schen Gesetzes,' *Zeitschrift für physikalische Chemie*, xiv. 1, 1894.

Boltzmann's Minimum Theorem.

42. The property that the functional equation (30) is a necessary as well as a sufficient condition of permanence was first proved by Boltzmann for a single monatomic gas in 1872,[1] for a mixture of two gases in 1886,[2] and both by Lorentz and by Boltzmann for a polyatomic gas in 1887.[3]

A similar investigation based on Boltzmann's was given by Burbury in 1890.[4] In his paper 'On the Collisions of Elastic Bodies,' Burbury has adapted the proof to colliding systems in general, and a similar generalisation is given in a better form by Watson.[5] Burbury's specification of the states of the systems by generalised co-ordinates and *velocities*, instead of *momenta*, is, to say the least, unfortunate, for the complete investigation involves considerations not only of collisions, but also of the free motions between collisions. Now, as we have seen in § 13, the multiple differential of the co-ordinates and *momenta* is an invariant in such motions. But the same is not necessarily true of the multiple differential of the co-ordinates and *velocities*; and even if the validity of the argument in § 13 of Burbury's paper be admitted, it only applies to rigid bodies under no forces. Watson obviates the difficulty by the use of generalised momenta, and arrives at the following result.

43. Let one of the co-ordinates q_n of one of the bodies be so chosen that a collision occurs whenever q_n attains its maximum value zero. Let H denote the function

$$\int \mathrm{F}(\log \mathrm{F} - 1)\, d\mathrm{P}_1 \ldots d\mathrm{Q}_m + \int f(\log f - 1)\, dp_1 \ldots dq_n \quad . \quad (34)$$

Then it is shown that

$$\frac{d\mathrm{H}}{dt} = \frac{1}{2}\int (\mathrm{F}'f' - \mathrm{F}f) \log \frac{\mathrm{F}f}{\mathrm{F}'f'}\, d\mathrm{P}_1 \ldots d\mathrm{Q}_m\, dp_1 \ldots dq_{n-1} \cdot \dot{q}_n \, . \quad (35)$$

and the latter integral is essentially negative; hence H diminishes with collisions until $\mathrm{F}'f' - \mathrm{F}f = 0$. Also H is constant in the absence of collisions, because the conditions of permanency then require F, f to be independent of the time. *Moreover, the multiple differentials* $d\mathrm{P}_1 \ldots d\mathrm{Q}_m$ *and* $dp_1 \ldots dq_n$ *are not affected by the choice of co-ordinates* (§ 14 above), and therefore no restriction is imposed on the generality of the conclusions by choosing q_n to vanish for any particular collision under consideration, nor does this choice affect the value of H.

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[1] 'Weitere Studien über das Wärmegleichgewicht unter Gasmolekülen,' *Sitzber. der k. Wiener Akad.*, lxvi. (ii.) (Oct. 1872), p. 275.

[2] 'Ueber die zum theoretischen Beweise des Avogadro'schen Gesetzes erforderlichen Voraussetzungen,' *Sitzber.* xciv. (ii.), Oct. 1886.

[3] 'Ueber das Gleichgewicht der lebendigen kraft unter Gasmolekülen,' 'Neuer Beweis zweier Sätze,' *Sitzber. der k. Wiener Akad.*, xcv. (iii.), Jan. 1887, pp. 115, 153.

[4] 'On some Problems in the Kinetic Theory of Gases,' *Phil. Mag.*, October 1890.

[5] *Kinetic Theory of Gases*, p. 42.

Also H cannot become minus infinity; therefore H diminishes to a minimum, and in the ultimate state of the system when H attains this minimum we have (30)

$$F'f'=Ff.$$

The quantity H has been called *Boltzmann's minimum function*,[1] and the above theorem may therefore be called *Boltzmann's minimum theorem.*

Rate of Subsidence of Disturbances.

44. Equations (25), (26) have been applied to calculate in certain cases the rate of subsidence of a disturbance in which $F'f'$ is initially unequal to Ff. In the paper already referred to Burbury has employed them to investigate the rate of subsidence of disturbance in the case of a medium of two sets of elastic spheres, the masses and numbers of spheres per unit volume of the two sets being M, m and N, n respectively, and the disturbance consisting in an initial small difference between the h constants in the two sets. He arrives at the result

$$D \propto e^{-\frac{1}{2}ct}, \quad d \propto e^{-\frac{1}{2}ct},$$

$$c=\frac{16}{3\sqrt{\pi}}(N+n)\frac{\sqrt{Mm}}{(M+m)^{\frac{3}{2}}}\cdot\frac{\pi s^2}{\sqrt{h}} \quad . \quad . \quad . \quad (36)$$

Here the h constants for the two sets are supposed to be $h\,(1+D)$ and $h\,(1+d)$: their arithmetic mean is h, and s is the sum of the radii of two spheres.

The same results had been previously found by quite independent methods by Tait[2] and Natanson,[3] both working under different assumptions.

Watson[4] has applied the same method to a number of lop-sided discs in one plane, supposing that in the disturbed state the average kinetic energy of rotation differs slightly from the two components of translational energy, so that the law of distribution is

$$A_0 e^{-\frac{M}{2}h(u^2+v^2+\mu k^2\omega^2)}\,du\,dv\,d\omega$$

where μ is different from unity. The result is given by

$$K=K_0 e^{-\alpha c^2 t/k^2}$$

where

$$\alpha=\frac{6CNs}{\sqrt{h_0}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (37)$$

and

$$K=N\log\frac{(2\mu+1)^{\frac{3}{2}}}{3^{\frac{3}{2}}\mu}$$

$$=N\left\{\frac{(\mu-1)^2}{6}+\text{higher powers of }\mu-1\right\}$$

C being a known numerical quantity.

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[1] Burbury, *Nature*, Dec. 14, 1893.

[2] *Trans. R.S.E.*, 1886, pp. 82, &c. See my first Report, §49, for his numerical results.

[3] L. Natanson, *Wied. Ann.*, xxxiii. 1888, p. 683.

[4] *Kinetic Theory of Gases*, p. 49.

Is the Boltzmann-Maxwell Distribution unique?

45. We have now found the necessary and sufficient conditions for a permanent or 'special' state to be—

(I.) f, F independent of time in the absence of collisions.

(II.) $Ff = F'f'$ for all collisions between two molecules.

Under these circumstances the principle of Conservation of Energy at once establishes the Boltzmann-Maxwell Law, which asserts that

$$F = A \exp - hE_P \qquad f = B \exp - hE_p$$

always give *a* solution of the problem.

Whether the Boltzmann-Maxwell distribution is *unique* depends on the possibility of finding other functions satisfying the above conditions, and it becomes necessary to discuss particular cases separately.

Case I.—*When no forces act*, the conservation of momentum parallel to any line chosen as the axis of x gives for masses M, m

$$MU + mu = MU' + mu'$$

and therefore the conditions are satisfied by

$$F \propto \exp kMU \qquad f \propto \exp kmu.$$

Combining this with the solution

$$F \propto \exp - hT_M \qquad f \propto \exp - hT_m$$

and writing $k = hu_0$ where u_0 is any constant, we obtain the solution

$$\left.\begin{aligned} F &= A \exp - \tfrac{1}{2}hm\,\{(U - u_0)^2 + V^2 + W^2\} \\ f &= B \exp - \tfrac{1}{2}hM\,\{(u - u_0)^2 + v^2 + w^2\} \end{aligned}\right\} \quad . \quad . \quad . \quad (38)$$

This is the law of distribution in a gas having what Burbury calls a 'motion of simple translation' and Boltzmann a 'progressive motion' of velocity u_0 along the axis of x; a result agreeing with those found by Burbury,[1] Boltzmann,[2] and others. Here the average molecular kinetic energies of the *relative motion*, taken with respect to a point moving with velocity u_0, are equal, so that the quantity which represents *temperature* is, as it should be, independent of u_0, the velocity of translation.

Case II.—*When the field is symmetrical about a fixed axis*, the constancy of angular momentum about this axis leads in a similar way to the distribution of co-ordinates and velocities among the molecules of a mass of rotating gas—such as that forming the atmosphere of a planet.

This case I have worked out in detail in Appendix B, and in conformity with the nomenclature of Case I. the gas may be said to have a 'motion of simple rotation.'

It is remarkable that in the paper last referred to Boltzmann,[3] while working out a number of problems on the motion of gases in a field of force, specially considers the case in which the gas has *no* initial motion of rotation. Maxwell, in the second part of the paper, discussed above in Section I., gives a long and laborious investigation relating to a free system of particles with constant linear and angular momenta;[1] but the formulæ, which are very long and complicated, do not appear to be applicable to the present problem, since they take no account of collisions between the various systems.

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[1] *Phil. Mag.*, October 1890, p. 305.

[2] 'Ueber das Wärmegleichgewicht von Gasen auf welche aussere Kräfte wirken,' *Sitzber. der k. Wiener Akad.*, lxxii. (ii.), Oct. 1875. 'Ueber die Aufstellung und Integration der Gleichungen welche die Molecularbewegung in Gasen bestimmen,' *Ibid.*, lxxiv. (ii.), Dec. 1876.

[3] 'Ueber die Aufstellung,' &c., *Wiener Sitzb.*, Dec. 1876.

CASE III.—*When each molecule has an axis of symmetry* the angular velocity Ω_3 or ω_3 about this axis is constant and unaltered by collisions, provided the molecules be regarded as perfectly smooth. Hence the law of distribution is independent of Ω_3 and ω_3, and these angular velocities may be distributed according to any law. This is not inconsistent with general conditions, for the collision formulæ $\Omega_3'=\Omega_3$ and $\omega_3'=\omega_3$ show that $Ff=F'f'$ is satisfied by any functions whatever of ω_3, Ω_3.

This case has already been alluded to in § 37 as furnishing an exception to the law obtained for lop-sided spheres. But its chief interest lies in the fact, pointed out by Boltzmann,[2] that since partition of energy only takes place among five of its six degrees of freedom, the ratio of the two specific heats

$$1+\frac{2}{m}=1+\frac{2}{5}=1{\cdot}4 \quad . \quad . \quad . \quad . \quad (39)$$

agreeing closely with the value found for air and most gases.

46. Except in the above cases and the still simpler case of smooth elastic spheres whose C.M. is at the centre, it will, I think, be found impossible to devise any form of *rigid bodies* in which the conditions of permanency are satisfied for all geometrically possible collisions otherwise than by the Boltzmann-Maxwell distribution. For example, the alternative distributions for non-colliding rigid bodies worked out in Appendix A cannot remain permanent unless the surfaces of the bodies are spherical, so that the line of collision always passes through their C.M. [This I have roughly verified by a process of 'exhaustion,' the details of which are uninteresting.]

In his aforementioned paper on the nature of gas molecules, Boltzmann considers the number of degrees of freedom of molecules generally in relation to the ratio of their specific heats, and arrives at the following conclusion: that 'the entire aggregate which forms a single gas molecule, and which can consist, not only of ponderable atoms, but also of ether atoms bound with them, probably behaves in its progressive motion and its collisions with other molecules nearly like a rigid body.'

The case of a polyatomic molecule, whose atoms are capable of vibrating relative to one another, affords an interesting field for investigation and speculation. Is the Boltzmann-Maxwell distribution still unique, or do other permanent distributions exist in which the kinetic energy is unequally divided between the momentoids?

Steady States under Permanent Disturbing Influence.

47. The important and highly interesting applications of the Kinetic Theory to disturbed states of a gas in which, by the action of external forces, a steady state differing from the Boltzmann-Maxwell distribution is maintained fall outside the scope of this Report. These include the problems

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[1] *Camb. Phil. Trans.*, 1879.

[2] 'Ueber die Natur der Gasmoleküle,' *Sitzb. der k. Wiener Akad.*, lxxiv. (ii.), 1876. He mentions this also in his paper translated in the *Phil. Mag.*, March 1893.

of steady flow of gases, viscosity, diffusion, heat conduction, chemical action, &c. Such questions form the subjects of investigations by Boltzmann,[1] Tait,[2] Burbury,[3] Natanson,[4] and other writers too numerous to mention. A complete list of papers would probably require a Report to itself, but the references in the accompanying footnotes may be of some assistance to those specially interested in the subject.

48. An entirely different class of problems has been treated by Lord Rayleigh in illustration of the properties of colliding bodies in general, considered especially with reference to the Kinetic Theory.[5] He considers the law of distribution of energy in a number of large masses, each of which is bombarded by streams of projectiles of much smaller mass moving in both directions in a straight line. If the projectiles are all moving with the same speed v, Lord Rayleigh finds that the velocities u of the bombarded masses will assume the Boltzmann-Maxwell distribution

$$f(u)=\mathrm{A}e^{-hu^2}$$

where the mean kinetic energy of the masses is *one half* that of each projectile.

If, however, the velocities of the projectiles themselves are distributed according to the Boltzmann-Maxwell distribution, the same is true of the bombarded masses, and the mean kinetic energies of the masses and projectiles are *equal*. Hence the *whole system*, consisting of the projectiles and masses, satisfies the Boltzmann-Maxwell distribution as defined in § 34. Lord Rayleigh goes on to consider the case when the free masses are replaced by pendulums under a one-sided or two-sided bombardment, and also gives an interesting investigation of the rate of progress towards the 'special' state, the motion in every case being one-dimensional.

Collisions replaced by Encounters.

49. Boltzmann has pointed out[6] that the effect of a collision between material points or monatomic molecules may equally well be represented by an encounter in which only attractive forces act. When the particles are at a certain distance apart he supposes a very great impulsive attraction to act on them, so that their directions of relative motion are refracted very nearly into the straight line joining them. When, after passing close together, they again come to the same distance, they undergo a second refraction under an impulsive attraction equal and opposite to the first, and the

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[1] 'Zur Theorie der Gasreibung,' *Sitzber. der k. Wiener Acad.*, lxxxi. (ii.), January 1880; lxxxiv. (ii.), June 1881, December 1881. 'Zur Theorie der Gasdiffusion,' *ibid.*, lxxxvi. (ii.), June 1882; lxxxviii. (ii.), October 1883. 'Bemerkungen über die Wärmeleitung der Gase,' *ibid.*, lxxii. (ii.), October 1875. Other papers are in the *Sitzungsberichte*, lvi. (ii.), November 1867, lxxv. (ii.), January 1887, xcvi. (ii.), October 1887; *Annalen der Physik und Chemie*, vol. xxii. 1884, p. 39.

[2] 'On the Foundations of the Kinetic Theory of Gases,' *Trans. Roy. Soc. Edin.*, 1886. See also my first Report for fuller references.

[3] *Phil. Mag.*, October 1890, p. 306, &c.

[4] 'Sur l'Interprétation cinétique de la Fonction de Dissipation,' *Comptes Rendus*, October 23, 1893, &c.; *Bulletin de l'Acad. des Sciences de Cracovie*, December 1893, p. 348.

[5] 'Dynamical Problems in Illustration of the Theory of Gases,' *Phil. Mag.*, November 1891.

[6] 'Ueber die Möglichkeit der Begründung einer kinetischen Gastheorie auf anziehende Kräfte allein,' *Annalen der Physik und Chemie*, xxiv. (1885), p. 37.

effect of both refractions on the ultimate motion is the same as that of a collision in which the line of centres is perpendicular to the direction of relative motion between the two refractions. And by making the relative velocity between the refractions very great, the duration of the encounter may be made very small. Boltzmann points out that an encounter involving three or more particles will sometimes have the effect of leaving two (or more) particles permanently entangled together, and the number of such double molecules will increase as the temperature and volume are decreased, thus suggesting an explanation of the phenomena of dissociation and liquefaction.

In the case of polyatomic molecules specified by generalised co-ordinates, the collision formula of § 33 cannot be directly applied to an encounter of this kind, owing to the changes of position of the molecules between the two refractions. But there would be no difficulty in here proving the Boltzmann-Maxwell Law by taking separate account of the two refractions and the free motion between them as explained in § 32.

50. The effect of double, treble, and multiple encounters in relation to the Boltzmann-Maxwell Law has been investigated by Natanson.[1] He arrives at conclusions entirely in accordance with what has been said above in § 30, and shows that the translational velocities of the C.M.'s of two or more molecules during an encounter follow the Boltzmann-Maxwell distribution. This may be readily verified as follows.

If the frequencies of distribution among two sets of molecules of masses m_1, m_2 are proportional to

$$e^{-h(T_1+\chi_1)} \quad \text{and} \quad e^{-h(T_2+\chi_2)}$$

then, as in § 30, the frequency of distribution of pairs of such molecules in the course of an encounter is proportional to

$$e^{-h(T_1+T_2+\chi_1+\chi_2+\chi_{12})} \quad . \quad . \quad . \quad . \quad . \quad (40)$$

where χ_{12} is the mutual potential energy due to the encounter, so that χ_{12} vanishes when the molecules are beyond the range of their mutual influence.

Now let u_1, v_1, w_1, u_2, v_2, w_2 be the translational velocities of the molecules, $\bar{u}, \bar{v}, \bar{w}$ those of their C.M., u_r, v_r, w_r the components of relative velocity. Then from

$$m_1u_1+m_2u_2=(m_1+m_2)\bar{u}$$
$$u_1 \sim u_2=u_r$$

we have total kinetic energy of translation of two molecules parallel to x

$$=\tfrac{1}{2}(m_1u_1{}^2+m_2u_2{}^2)=\tfrac{1}{2}(m_1+m_2)\bar{u}^2+\tfrac{1}{2}\frac{m_1m_2}{m_1+m_2}u_r{}^2 \quad . \quad . \quad (41)$$

whence it readily follows from (40) that the mean energy of translation of the whole mass m_1+m_2 collected at the C.M. is equal to $3/2h$, and is equal to the mean translational energy of either of the separate molecules. And by combining the translational energy of the pair with that of a third molecule the result can be extended to any number of molecules.

In my first Report, § 43, I alluded to some difficulties raised by Tait regarding the question of temperature, but the present conclusions show that no such difficulties arise in connection with the Boltzmann-Maxwell

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[1] 'Ueber die kinetische Theorie unvollkommener Gase,' *Annalen der Physik und Chemie*, xxxiii. (1885), p. 685.

Law at any rate. For, taking $3/2h$ as the measure of the temperature, we see that it is—

(i) The mean kinetic energy of translation per *free* molecule.
(ii) The mean kinetic energy of translation of the molecules in an encounter for any given configuration of the system.
(iii) The mean kinetic energy of the C.M. of two or more encountering molecules found by supposing their whole mass concentrated at this C.M.

If the volume of the gas be increased, the number of encountering molecules will be decreased, but their mean kinetic energy will still be equal to that of the free molecules.

51. The proof of the Boltzmann-Maxwell Law thus presents little difficulty when collisions are replaced by encounters lasting only a limited time, so that the molecules are sometimes free and sometimes in the process of an encounter, even though these encounters be multiple. But it fails when the molecules act on one another at all distances, because we cannot then consider any group of molecules apart from the rest. Moreover, unless collisions or encounters take place to a certain extent indiscriminately between molecules, the frequency of distribution for any particular molecule may depend on other circumstances besides its actual state, and the assumptions made in proving the equation $Ff = F'f'$ (§ 39) are no longer necessarily true. Hence, none of the above arguments now afford any evidence that in such cases the Boltzmann-Maxwell distribution is the distribution which a gas naturally tends to assume, even though the possibility of such a distribution may not be capable of disproof.

Thus, in the test case of molecules attracting one another according to the law of the direct distance, they will if initially arranged according to the Boltzmann-Maxwell Law remain so distributed; but this law of permanent distribution is not unique, nor is there any tendency among the molecules to attain this law.

In dealing with such forces as that due to *gravitation*, as in the case of a gaseous nebula held together by the attraction of its parts, it is clear that the attraction of the more distant portions of the gas can be represented by a field of external force whose potential is the gravitation potential of the mass. Thus no difficulty will be introduced into the proof of the Boltzmann-Maxwell Law, except when we come to take account of the attractions of those molecules that are very near any given molecule. These are probably feeble, except in an encounter. The problem, however, requires fuller treatment than can be given in the space of this Report.

SECTION III.—THE BOLTZMANN-MAXWELL LAW CONSIDERED IN RELATION TO OTHER THEORIES.

The Connection with the Theory of Probability.

52. The application of the Theory of Probability to the determination of the law of distribution among gas-molecules forms the subject of several very interesting and suggestive papers in the hands of Boltzmann and Burbury.

I have ventured, on my own responsibility, to introduce the well-known terms '*à priori*' and '*à posteriori* probability' in the following accounts, as, personally, I think they make the matter clearer. They are not Boltzmann's.

In his first paper[1] Boltzmann starts by taking a finite number n of molecules, and supposing that the kinetic energy of each molecule must have one or other of a discrete series of values ϵ, 2ϵ, 3ϵ, . . . $p\epsilon$. Taking the total energy T of the system as equal to $\lambda\epsilon$, he investigates the probability that it should be divided between the molecules in a given manner, each value of the energy being *à priori* equally probable for a given molecule. If ω_0, ω_1, ω_2, . . . ω_p be the numbers of molecules having energies 0, ϵ, 2ϵ, . . . $p\epsilon$, the number of permutations of molecules satisfying this distribution or 'complexion' is

$$\mathfrak{P}=\frac{n\,!}{\omega_0\,!\;\omega_1\,!\;.\;.\quad\omega_p!}\quad .\quad .\quad .\quad .\quad (42)$$

subject to the conditions

$$\omega_0+\omega_2+\;.\;.\;.\;+\omega_p\;=n\;.\quad .\quad .\quad .\quad (43)$$

$$\omega_1+2\omega_2+\;.\;.\;.\;+p\omega_p=\lambda\;.\quad .\quad .\quad .\quad (44)$$

The *à posteriori* most probable distribution is that for which the number of permutations is greatest. Taking M to be the logarithm of the denominator of $\mathfrak{P}$, or

$$\mathrm{M}=\log\,(\omega_0\,!)+\log\,(\omega_1\,!)+\;.\quad .\quad .\quad .\quad (45)$$

we have, therefore to make M a minimum subject to the conditions (43) (44). To simplifiy the calculation, when ω is very great, ω ! may be replaced by its approximate value

$$\sqrt{(2\pi)}\left(\frac{\omega}{e}\right)^{\omega}\quad .\quad .\quad .\quad .\quad .\quad (46)$$

Passing to the case in which the energy is capable of continuous variation, if $f\,(x)\,dx$ denote the number of molecules with energy between x and $x+dx$, we have to put $\omega_0=\epsilon f\,(0)$, $\omega_1=\epsilon f(\epsilon)$, . . . $\omega_p=\epsilon f\,(p\epsilon)$, and to make $\epsilon=dx$ in the limit, so that the problem reduces to finding the minimum of

$$\mathrm{M}'=\int_0^\infty f\,(x)\,\log f\,(x)\,dx\quad .\quad .\quad .\quad .\quad (47)$$

subject to the conditions

$$n=\int_0^\infty f\,(x)\,dx\,.\quad .\quad .\quad .\quad .\quad .\quad (48)$$

$$\mathrm{T}=\int_0^\infty xf\,(x)\,dx\quad .\quad .\quad .\quad .\quad .\quad (49)$$

where M′ differs from M by a constant, and is what Boltzmann calls the 'measure of permutability.'

The solution is

$$f\,(x)\,dx=\mathrm{C}e^{-hx}\,dx\quad .\quad .\quad .\quad .\quad .\quad (50)$$

This, therefore, is the *à posteriori* most probable distribution of the energy among the molecules on the hypothesis that the *à priori* probabilities of all energies are equal for any one molecule. If m is the mass of a molecule, the most probable number of molecules with speeds between u and $u+du$ is

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[1] 'Ueber die Beziehung zwischen dem zweiten Hauptsatz der mechanischen Wärmetheorie und der Warscheinlichkeitsrechnung respective den Satzen über das Wärmegleichgewicht,' *Sitzber. der k. Wiener Akad.*, lxxvi. (ii.), Oct. 1878.

$$Ce^{-\frac{1}{2}hmu^2}\,mudu \quad . \quad . \quad . \quad . \quad . \quad (51)$$

This is the Boltzmann-Maxwell distribution of speed for a system of monatomic molecules *moving in one plane.*

53. To obtain the Boltzmann-Maxwell distribution for molecules moving in three dimensions, Boltzmann finds it necessary to make a different assumption with regard to the *à priori* probabilities. He assumes, in fact, that if u, v, w be the velocities along the axes of co-ordinates, all values of u, v, w are *à priori* equally probable. The problem of determining the *à posteriori* most probable distribution therefore reduces to finding the minimum of

$$\iiint f\log f\,.\,du\,dv\,dw = -\Omega \text{ suppose} \quad . \quad . \quad . \quad (52)$$

subject to the conditions

$$n=\iiint f\,du\,dv\,dw \quad . \quad . \quad . \quad . \quad . \quad . \quad (53)$$

$$\mathrm{T}=\tfrac{1}{2}m\iiint (u^2+v^2+w^2)\,du\,dv\,dw \quad . \quad . \quad . \quad (54)$$

For the general case of molecules with r degrees of freedom in a field of force, he assumes that all values of the co-ordinates and momenta p are *à priori* equally probable.

This is the assumption that would be fulfilled if the values were selected by drawings from an urn containing tickets, each ticket having a set of values of $p_1 \ldots q_r$ inscribed on it, and the number of tickets in which these values lie between the limits $dp_1 \ldots dq_r$ being measured by the product of the multiple differential $dp_1 \ldots dq_r$ into a constant. In the case of a mixture of gases there would have to be a number of urns equal to the number of gases, and the number of tickets drawn from each urn would have to equal the number of molecules of the gas in question in the mixture.

The final result is that the *à posteriori* most probable distribution is that for which the function

$$-\Omega=\sum\int f\log f\,dp_1 \ldots dq_r \,. \quad . \quad . \quad (55)$$

is a minimum, Σ referring to the different kinds of molecules in a mixture of several gases.

The expression $-\Omega$ differs by a constant from *Boltzmann's Minimum Function.*

We have seen in § 43 that, when there are collisions between the molecules, this function always tends to a minimum until the Boltzmann-Maxwell distribution is attained, and the present investigation therefore shows that the gas tends to pass from distributions of lesser probability to distributions of greater probability, until it attains the most probable distribution of all—namely, the Boltzmann-Maxwell distribution.

Finally, Boltzmann proves that the function Ω is proportional to the entropy (plus a constant), thus affording a verification of the theorem that the entropy of a system tends to a minimum. The identification of Boltzmann's minimum function with the entropy is established more briefly by Burbury in his recent paper, to be discussed shortly.[1]

54. The particular assumption as to the law of *à priori* probability precludes the above investigations from furnishing a complete proof of the Boltzmann-Maxwell Law. In a subsequent paper[2] Boltzmann has removed this restriction, and has considered the *à posteriori* probabilities corresponding to any assumed law of *à priori* probability. In other words, we start with a large number (N) of molecules having a given distribution of energy, and from them a smaller number (n) are selected, and their mean energy is found to have a certain value which may be either the same or different from that of the original N. It is required to find the most probable law of distribution in the n selected molecules, or, generally, the probability of any given distribution.

Boltzmann first considers the case where the original molecules follow the Boltzmann-Maxwell Law for two dimensional space, and points out the necessary modifications for space of three dimensions. In the general case, supposing $f_1, f_2, \ldots f_p$ to denote the *à priori* probabilities of a molecule having energies $\epsilon, 2\epsilon, \ldots p\epsilon$, the *à posteriori* probability of a combination in which the numbers of molecules having these energies are $\omega_0, \omega_1, \ldots \omega_p$ respectively is proportional to Ω, where

$$\Omega = f_0^{\omega_0} f_1^{\omega_1} \ldots f_p^{\omega_p} \frac{n\,!}{\omega_0\,!\,\omega_1\,!\,\omega_2\,!\cdots} \quad \ldots \quad (56)$$

where as before

$$\sum \omega_i = n \qquad \sum i\omega_i = \lambda.$$

The approximate expression for $\omega\,!$ now gives

$$\log \Omega = \sum \omega_i \log f_i - \sum \omega_i \log \omega_i + \text{constant}$$

and Boltzmann finds the following results.

If the mean energy of the selected n molecules is equal to the mean energy of the original N, the most probable distribution of energy in the latter is identical with the distribution in the former.

If, however, the mean energy of the smaller number is unequal to that of the larger, the most probable distribution is that given by the form

$$\omega_k = \frac{an}{\mathrm{N}} f_k e^{-hk\epsilon} \quad \ldots \quad (57)$$

Boltzmann's investigation was *probably* an attempt to arrive at the Boltzmann-Maxwell distribution as the ultimate result of a number of successive processes such as the above, independently of the initial distribution. This has recently been actually accomplished by Burbury by the application of a different method as follows :—

55. Burbury[3] bases his investigation on a generalisation of the theory of Least Squares, which asserts that if we regard the variations of a series of n quantities $x_1, x_2, \ldots x_n$ as being each the result of an infinite number N of independent simultaneous increments divided each by $\sqrt{\mathrm{N}}$, then the

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[1] 'On the Law of Distribution of Energy,' *Phil. Mag.*, January 1894.

[2] 'Weitere Bemerkungen über einige Probleme der mechanischen Wärmetheorie,' *Sitzb. der k. Wiener Akad.*, lxxviii. (ii.), June 1878. The second part of the paper deals with the equilibrium of a gas under gravity, and is less interesting.

[3] *Phil. Mag.*, January 1894.

chance that the values of x_1, x_2 . . . shall lie between c_1 and c_1+dc_1, c_2 and c_2+dc_2, &c., is proportional to an expression of the form

$$e^{-\frac{n\mathrm{S}}{2\mathrm{T}}}\,dc_1\,dc_2\,.\,.\,.\,dc_n \quad . \quad . \quad . \quad . \quad (58)$$

where S is a certain homogeneous quadratic function of the c's, and T a constant. This result, which for a single variable leads to the well-known error-law, is independent of the original law of distribution of the increments, provided that positive and negative values of these increments are equally probable.

Taking S as proportional to the kinetic energy of a system, and supposing the number of such systems to be very great, Burbury next shows that if a redistribution of S among the systems is effected in a certain way, the ultimate result will be the Boltzmann-Maxwell distribution, and this will remain unaffected by any further redistribution. The method of redistribution is such that energy is conserved in the final result, but not in the intermediate processes, and Burbury suggests that the process of redistribution of energy between the molecules may be effected by waves transmitted through the ether. The proof requires us to assume that these waves satisfy the principle of superposition, otherwise the law cannot be permanent. The author, however, claims that the method is applicable to systems in which no group of molecules is ever free from the action of other parts of the system, and for which those proofs of the Boltzmann-Maxwell Law treated in Sections I., II. of this Report fail.

Burbury then finds the expression for Boltzmann's minimum function, and calling this B he verifies that the entropy of the system is equal to $-2\mathrm{B}/n$ (plus a constant). The whole treatment is very powerful and suggestive, and the paper opens up a wide field for discussion and speculation.

56. The assumption in the first place that each molecule is capable of assuming only a discrete instead of a continuous series of different states, the number of these states being made infinite in the limit, forms the basis of Boltzmann's proof of his Minimum Theorem for polyatomic gas-molecules.[1] Natanson,[2] taking Boltzmann's starting-point of a number of systems whose energies can only have one of a series of discrete values

$$\epsilon,\ 2\epsilon,\ .\ .\ .\ p\epsilon$$

and employing equations (43) (44) above, has worked out the final distribution of energy among the molecules on the supposition that interchange of energy takes place by collisions, and he has also determined the rate at which the system approaches the Boltzmann-Maxwell distribution. He gives a complete solution of the problem for the particular case where $p=3$, and shows that only analytical difficulties prevent the method from being applied to higher values of p. When, however, p is made infinite, the results agree with those found by Boltzmann and by Tait (§ 44).

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[1] 'Neuer Beweis zweier Sätze,' *Sitzber. der k. Wiener Akad.*, xcv. (ii.), Jan. 1887, p. 153.

[2] 'Ueber die Geschwindigkeit mit welcher Gase den Maxwell'schen Zustand erreichen,' *Annalen der Physik und Chemie*, xxxiv. (1888).

The Connection between the Virial Equation, the Second Law, and the Boltzmann-Maxwell Law.

57. The virial equation cannot be used to *prove* the Second Law. When applied to a perfect gas it leads to the equation

$$pv = R\theta \quad . \quad . \quad . \quad . \quad . \quad (59)$$

From this equation, combined with the Second Law, certain properties of perfect gases, with which we are all familiar, are deduced in treatises on thermodynamics. These are that the latent heat of expansion is equal to the pressure, that the difference of specific heats is equal to R, and so on. Hence corresponding conditions must hold good in molecular thermodynamics in order that the Second Law may be consistent with the virial equation.

A general condition under which the Second Law is true was originally found by R. C. Nichols,[1] and has recently been put into a somewhat different form by Burbury.[2] If χ or U denote the potential energy, this condition may be written

$$\frac{1}{T}\left(\frac{d}{dv}\chi - \overline{\frac{d\chi}{dv}}\right) = -\frac{d}{dt}\overline{\frac{d\chi}{dv}} \quad . \quad . \quad . \quad . \quad (60)$$

where the bar denotes average values.

Burbury[3] has rightly pointed out that the methods of Clausius and Szily[4] require such a condition to be satisfied in order that they may give the Second Law. The condition comes in when we try to assign a meaning to the 'quasi-period *i*,' without which meaning the result is unintelligible. Burbury shows that if we assume

$$i = v^{\frac{1}{3}}T^{-\frac{1}{2}} \text{ (}i.e.\text{, a definite } time\text{)},$$

then χ must be a function of v only, so that

$$\frac{d}{dv}\bar{\chi} = \overline{\frac{d\chi}{dv}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (61)$$

and this is a special case of Nichols' condition.

It is also to be observed that in the Clausius-Szily method the averages are *time-averages*. This, if not an objection, is at least a disadvantage, since it does not show the relation between the Second Law and the Boltzmann-Maxwell Law, in which averages are taken over a large number of molecules in a 'special state' of permanent distribution.

58. That relation forms the subject of a very recent paper by Burbury,[5] which is a development of his second letter to 'Nature.'[6]

The proof of the Second Law on the assumption of the Boltzmann-Maxwell Law has long been known, and was given by Boltzmann as early as 1871,[1] and by Burbury in 1876.[2] Burbury now treats the converse problem of determining the law of distribution from the Second Law. He finds that if the law of distribution of the co-ordinates $x_1, x_2, \ldots x_n$ be given by the expression

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[1] 'On the Proof of the Second Law of Thermodynamics,' *Phil. Mag.*, 1876 (i.), p. 369.

[2] *Nature*, December 14, 1893; January 11, 1894.

[3] *Ibid.*, December 14, 1893.

[4] 'Report on Thermodynamics,' Part I. Section 1, *Cardiff Report*, 1891, p. 88.

[5] 'The Second Law of Thermodynamics,' *Phil. Mag.*, June 1894, p. 574.

[6] *Nature*, Jan. 11, 1894.

$$\mathrm{N}f(x_1, x_2, \ldots x_n)\,dx_1 \ldots dx_n \text{ or } \mathrm{N}f d\sigma,$$

and if the law of distribution of co-ordinates and velocities be given by

$$\mathrm{F}d\sigma\, d\sigma' \text{ where } d\sigma' = d\dot{x}_1 \ldots d\dot{x}_n,$$

then $\partial\mathrm{Q}/\mathrm{T}$ will be a complete differential if either

(i) $$\mathrm{F} = \text{function of } (\tau - \mathrm{U})/\mathrm{T} = \phi\{(\tau - \mathrm{U})/\mathrm{T}\} \text{ say} \quad . \quad (62)$$

(which does not vanish for infinite values of the variables), or

(ii) $$\mathrm{F} = \phi\left(\frac{\tau + \mathrm{U}}{\mathrm{T}}\right), \qquad f = \psi\left(\frac{\mathrm{U}}{\mathrm{T}}\right) \quad . \quad . \quad . \quad . \quad (63)$$

where τ is the kinetic energy, and U the potential energy of a molecule.

Burbury says: 'And since F and f must vanish for all infinite values of the variables, we are led to

$$\mathrm{F} = \mathrm{C} \exp -\lambda \frac{\mathrm{U} + \tau}{\mathrm{T}} \qquad f = \mathrm{C}' \exp -\lambda \frac{\mathrm{U}}{\mathrm{T}}$$

where λ is some positive numerical quantity. . . .'

59. Now this is obviously a solution, but it is not the *only* solution, and I think the real inferences are slightly different from those he has drawn. They are sufficiently interesting to be treated in detail, and they are intimately connected with another point which at first suggests an objection to the proof, namely, that $d\sigma\, d\sigma'$ is the multiple differential of the co-ordinates and *velocities*, and is therefore not in general an invariant like the multiple differential of the co-ordinates and *momenta*.

In § 15 of his paper Burbury states that this does not matter. 'If they' (*i.e.*, $d\sigma$ and $d\sigma'$) 'do vary, that is, in effect, if the limits of integration vary, the assumption $\mathrm{F} = \phi\{(\mathrm{U} + \tau)/\mathrm{T}\}$ will still make $\partial\mathrm{Q}/\mathrm{T}$ a complete differential.'

Now if $y_1, \ldots y_n$ denote the generalised *momenta* corresponding to the co-ordinates $x_1 \ldots x_n$, the Jacobian

$$\frac{\partial(\dot{x}_1, \ldots \dot{x}_n)}{\partial(y_1, \ldots y_n)} = \mathrm{J}(x_1, x_2 \ldots x_n) \text{ suppose}$$

will in general be a function of the co-ordinates $x_1, \ldots x_n$, and its form will depend on the choice of co-ordinates.

Hence, *if Burbury's proof be correct*, we have really shown that the Second Law will be satisfied if the distribution be determined by *any* expression of the form

$$\phi\left(\frac{\mathrm{U} + \tau}{\mathrm{T}}\right) \mathrm{J}(x_1, \ldots x_n)\,dx_1 \ldots dx_n\,dy_1 \ldots dy_n \quad . \quad (64)$$

where by suitable choice of co-ordinates the form of J may be varied quite arbitrarily. And by § 22 this expression represents, not necessarily the Boltzmann-Maxwell distribution, but a distribution satisfying the condition that if the kinetic energy be reduced to a sum of n squares, the mean values of these squares are equal. Hence the conclusion may be stated thus:—

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[1] 'Analytische Beweise des zweiten Hauptsatzes,' &c., *Sitzber. der k. Wiener Akad.*, lxiii. (ii.), 1871, p. 712.

[2] *Phil. Mag.*, January 1876, p. 61.

If the necessity for making $\partial Q/T$ a complete differential can be established as a substantive law by independent evidence, the investigation affords an independent proof of *Maxwell's law of partition of kinetic energy* between the momentoids for such a system.

Conclusion.

60. The conclusions arrived at in the present Report are to be regarded as superseding the statement of Clerk Maxwell's Theorem in §40 and the greater part of §§ 41, 42, 43 of Section III. of my first Report. The rest of that Report is not, so far as it goes, materially affected by any results now established, although several important questions connected with the Boltzmann-Maxwell Law have now received a definite answer.

The proof of the law and the assumptions involved in it are fairly satisfactory for gases whose molecules collide with each other to a certain extent at random, but in a medium in which the molecules never escape from each other's influence the subject still presents very great difficulties.

Even should it be shown that the law cannot be *disproved* for such a medium, there still remains the question as to whether the distribution is the *unique* one satisfying the conditions of permanence. The general question of uniqueness, even in some of the cases where the law admits of more or less satisfactory proof, still suggests some questions for investigation. Intimately connected with this is the difficult question of *stability*. For example, when a gas is condensed, its density at any point at first remains proportional to e^{-hx} in accordance with the Boltzmann-Maxwell Law; but when a certain stage is reached, instability sets in, and part of the gas liquefies. If the Second Law be true, the new distribution satisfies Maxwell's law of partition of energy. Does it likewise satisfy the Boltzmann-Maxwell Law?

The connection with the Theory of Probability still suggests subjects for research. The relations of electrical and optical phenomena to the Kinetic Theory open up an almost unexplored field.

61. It only remains for me to thank all those who have assisted me in collecting materials for this Report. I am particularly indebted to Dr. Ludwig Boltzmann for his kindness in sending me copies of nearly all his writings, and for several valuable suggestions that have helped to clear up difficulties in the work. My thanks are also due to Mr. Burbury, Dr. Ladislaus Natanson, Professor Sydney Young, and others for similar help, which has very materially lightened the work of consulting and examining the large mass of existing literature relating to this most interesting branch of Mathematical Physics.

APPENDIX A.

The Possible Laws of Partition of Rotatory Energy in Non-colliding Rigid Bodies.

The motion of a rigid body about a fixed point or about its centre of mass under no forces affords one of the best test cases bearing on Maxwell's law of partition of kinetic energy.

The equations of motion referred to the principal axes are of the form

$$A\frac{d\omega_1}{dt}-(B-C)\,\omega_2\omega_3=0 \quad . \quad . \quad . \quad . \quad (65)$$

and the kinetic energy is

$$T=\tfrac{1}{2}(A\omega_1^2+B\omega_2^2+C\omega_3^2) \quad . \quad . \quad . \quad . \quad (66)$$

Let Ω_1, Ω_2, Ω_3 be the initial angular velocities about the principal axes, and let

$$\Delta=\frac{\partial(\omega_1,\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)} \quad . \quad . \quad . \quad . \quad . \quad (67)$$

Then

$$\frac{d\Delta}{dt}=\frac{\partial(\dot\omega_1,\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}+\frac{\partial(\omega_1,\dot\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}+\frac{\partial(\omega_1,\omega_2,\dot\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}.$$

But by (i)

$$A\frac{\partial(\dot\omega_1,\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}=(B-C)\left\{\omega_2\frac{\partial(\omega_3,\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}+\omega_3\frac{\partial(\omega_2,\omega_2,\omega_3)}{\partial(\Omega_1,\Omega_2,\Omega_3)}\right\}$$
$$=0,$$

since each of the two determinants has two rows or columns equal. Therefore

$$\frac{d\Delta}{dt}=0$$

and

$$\Delta=\text{const.}=1,\ \text{(its initial value)} \quad . \quad . \quad . \quad (68)$$

Since T=constant for any body, it follows that if a very large number (N) of such rigid bodies have their angular velocities initially so distributed that the number with angular velocities between Ω_1 and $\Omega_1+d\Omega_1$, Ω_2 and $\Omega_2+d\Omega_2$, Ω_3 and $\Omega_3+d\Omega_3$ is

$$Nf(T)\,d\Omega_1 d\Omega_2 d\Omega_3$$

the distribution of any subsequent time will be given by

$$Nf(T)\,d\omega_1 d\omega_2 d\omega_3 \quad . \quad . \quad . \quad . \quad . \quad (69)$$

and therefore distribution will be permanent.

With this distribution it is easy to see that at any instant the average values of

$$\tfrac{1}{2}A\omega_1^2,\quad \tfrac{1}{2}B\omega_2^2,\quad \tfrac{1}{2}C\omega_3^2$$

over the different bodies are equal to one another, so that Maxwell's law of partition of kinetic energy is satisfied.

But the equations of motion have a second integral expressing the constancy of resultant angular momentum, namely,

$$A^2\omega_1^2+B^2\omega_2^2+C^2\omega_3^2=G^2=\text{const.} \quad . \quad . \quad . \quad (70)$$

Hence any distribution given by

$$Nf(G)\,d\omega_1 d\omega_2 d\omega_3 \quad . \quad . \quad . \quad . \quad . \quad (71)$$

will (in the absence of collisions between the bodies) be permanent.

And it can now be shown precisely in the same way as before that the mean values of

$$A^2\omega_1^2, \quad B^2\omega_2^2, \quad C^2\omega_3^2$$

are equal to one another.

Therefore the mean values of

$$\tfrac{1}{2}A\omega_1^2, \quad \tfrac{1}{2}B\omega_2^2, \quad \tfrac{1}{2}C\omega_3^2$$

are now inversely proportional to A, B, C, *and Maxwell's law of partition of energy does not hold good.*

It is only when the distribution of velocities or momenta is determined by a function f *of the energy alone* that we can assert that the mean values of the different squares forming the kinetic energy are equal.

APPENDIX B.

On the Law of Molecular Distribution in the Atmosphere of a Rotating Planet.

Suppose a mass of gas-molecules to be situated in a field of force that is symmetrical about a fixed axis—for example, the field due to the attraction of a spheroidal planet.

Let this axis be chosen as the axis of z, and, in the first place, let the molecules be monatomic, so that they may be regarded as smooth homogeneous spheres or material points.

Let m, M be the masses of two molecules, E_m, E_M their total energies, p, P their angular momenta about the axis of z, so that

$$p=m(vx-uy) \qquad P=M(VX-UY) \quad . \quad . \ (72)$$

Then, since the field is symmetrical, the angular momenta p, P are constant in the absence of collisions, and at a collision the total angular momentum is unaltered, so that

$$p+P=p'+P'$$

Also similar relations are satisfied by the energies E_m, E_M.

Therefore, if the distributions of co-ordinates and velocities be given by the expressions

$$f\,dx\,dy\,dz\,du\,dv\,dw \text{ and } F\,dX\,dY\,dZ\,dU\,dV\,dW,$$

the conditions of permanence between collisions, and the functional equation for collisions

$$fF=f'F'$$

are satisfied by

$$f=n\exp-(hE_m-kp) \qquad F=N\exp-(hE_M-kP)$$

where h, k are any constants whatever. Putting $k=h\Omega$, we have, if χ be the potential energy of m,

$$f=n\exp-h(T-\Omega p+\chi)$$
$$=n\exp-h\{\tfrac{1}{2}m(u^2+v^2+w^2)-m\Omega(vx-uy)+\chi\}$$
$$=n\exp-h\{\tfrac{1}{2}m[(u+\Omega y)^2+(v-\Omega x)^2+w^2]+\chi-\tfrac{1}{2}m\Omega^2(x^2+y^2)\} \quad (73)$$

Take axes of ξ, η, ζ rotating about the axis of z with angular velocity Ω and instantaneously coinciding with the axes of x, y, z.

Then the *relative* velocities of a molecule referred to these moving axes are

$$\dot\xi = u + \Omega y, \qquad \dot\eta = v - \Omega x, \qquad \dot\zeta = w$$

and we at once find

$$\frac{\partial(\dot\xi, \dot\eta, \dot\zeta)}{\partial(u, v, w)} = 1$$

Hence the distribution may be written

$$n \exp - h\left\{\tfrac{1}{2}m(\dot\xi^2+\dot\eta^2+\dot\zeta^2)+\chi-\tfrac{1}{2}m\Omega^2(\xi^2+\eta^2)\right\} \,.\, d\xi\, d\eta\, d\zeta\, d\dot\xi\, d\dot\eta\, d\dot\zeta \quad . \quad (74)$$

Therefore the velocities *relative* to the moving axes follow the Boltzmann-Maxwell distribution, and in addition to this the molecules have a superposed motion of rigid-body-rotation with angular velocity Ω. And the density at any point is the same as if the gas were acted on by 'centrifugal force' having a potential $-\frac{1}{2}\Omega^2(\xi^2+\eta^2)$, and the reversed angular velocity $-\Omega$ were applied to every molecule.

Hence the Kinetic Theory may be applied to the atmospheres of planets by reducing the planets to rest and applying centrifugal force to the atmospheres in the usual way.

It is interesting to notice that the temperature $3/2h$ is the mean kinetic energy of the translational motion *relative to the planet* and not the total mean translational energy.

The results can evidently be generalised for the case when the molecules are rigid bodies of any kind. Let $\omega_x, \omega_y, \omega_z$ be the angular velocities of such a molecule about axes through its C.M. parallel to the axes of x, y, z, and let $\omega_1, \omega_2, \omega_3$ be its angular velocities about its principal axes. By Appendix I., $d\omega_1\, d\omega_2\, d\omega_3$ is independent of the time, and evidently

$$\frac{\partial(\omega_x, \omega_y, \omega_z)}{\partial(\omega_1, \omega_2, \omega_3)} = \left\{\begin{matrix}\text{determinant of the direction cosines}\\ \text{between the two sets of axes}\end{matrix}\right\} = 1$$

Hence the permanent distribution is of the form

$$n \exp - h(\mathrm{T} - \Omega p + \chi) \,.\, dx\, dy\, dz\, du\, dv\, dw\, d\omega_x\, d\omega_y\, d\omega_z$$

Now if A, B, C, D, E, F denote the moments and products of inertia, the kinetic energy of rotation of the molecule is

$$\mathrm{T}_\omega = \tfrac{1}{2}(\mathrm{A}, \mathrm{B}, \mathrm{C}, -\mathrm{D}, -\mathrm{E}, -\mathrm{F}\,)(\,\omega_x, \omega_y, \omega_z)^2$$

also

$$p = m(vx - uy) + \frac{d\mathrm{T}_\omega}{d\omega} \quad . \quad . \quad . \quad . \quad (75)$$

therefore

$$\begin{aligned}\mathrm{T} - \Omega p + \chi = {} & \tfrac{1}{2}m\left[(u+\Omega y)^2+(v-\Omega x)^2+w^2\right]-\tfrac{1}{2}m\Omega^2(x^2+y^2)\\ & +\tfrac{1}{2}(\mathrm{A}, \mathrm{B}, \mathrm{C}, -\mathrm{D}, -\mathrm{E}, -\mathrm{F}\,)(\,\omega_x, \omega_y, \omega_z-\Omega)^2-\tfrac{1}{2}\mathrm{C}\Omega^2+\chi\end{aligned}$$

and since evidently

$$\omega_x = \omega_\xi, \quad \omega_y = \omega_\eta, \quad \omega_z - \Omega = \omega_\zeta$$

therefore

$$\begin{aligned}f = n \exp - h\Big\{ & \tfrac{1}{2}m(\dot\xi^2+\dot\eta^2+\dot\zeta^2)+\tfrac{1}{2}(\mathrm{A}, \mathrm{B}, \mathrm{C}, -\mathrm{D}, -\mathrm{E}, -\mathrm{F}\,)(\,\omega_\xi, \omega_\eta, \omega_\zeta)^2\\ & -\tfrac{1}{2}m\Omega^2(\xi^2+\eta^2)-\tfrac{1}{4}\mathrm{C}\Omega^2+\chi\Big\} \quad . \quad . \quad . \quad . \quad (7\end{aligned}$$

Here the potential energy of centrifugal force is

$$-\tfrac{1}{2}m\Omega^2(\xi^2+\eta^2)-\tfrac{1}{2}C\Omega^2$$

and therefore the law of distribution

$$f=n\exp-h\{T_r+\chi+V_\Omega\} \quad . \quad . \quad . \quad . \quad (77)$$

where T_r is the kinetic energy of the relative motion;
χ is the potential energy due to the field;
V_Ω is the potential energy due to centrifugal force.

Hence, as before, the Boltzmann-Maxwell Law holds for the system obtained by applying the reversed angular velocity $-\Omega$ and the centrifugal force whose potential is $-\frac{1}{2}\Omega^2(x^2+y^2)$ at every point of the gas.

It would not be difficult to extend the proof to the case of a rotating ellipsoidal planet with three unequal axes, where the field of force is not symmetrical about the axes of rotation, but the investigation would hardly be sufficiently interesting to be worth giving in detail. It will also be admitted, without difficulty, that similar conclusions must hold good when the planet and atmosphere besides rotating have a common motion of simple translation.

In a communication read at the Nottingham meeting of the Association[1] I worked out certain results of applying the Boltzmann-Maxwell Law to the atmospheres of planets; but in these calculations no account was taken of axial rotation, as I did not at that time see how the effect of this rotation could be determined. The numerical results there obtained hold good, without modification, at points *along the polar axes* of the various bodies considered. The effects of centrifugal force on the distributions now furnish a promising subject for future investigation, about which I hope to say more shortly.

APPENDIX C.

On the Application of the Determinantal Relation to the Kinetic Theory of Polyatomic Gases. By Professor LUDWIG BOLTZMANN.

We shall consider a gas whose molecules are compound (or polyatomic), but are all similarly constituted. Let $a, b, c, \ldots$ be the co-ordinates which determine the position and configuration of a molecule of such a gas; and let $p, q, r, \ldots$ be the corresponding momenta. Let us suppose that the time during which any one molecule acts upon or is acted upon by other molecules is short in comparison with the whole time of its motion. Let the gas be contained in a vessel of invariable form. After a certain time the state of the gas will become stationary, and the question is, what is then the probability that the co-ordinates and momenta of any one molecule lie between certain limits? To express the probability by means of a number let us suppose the stationary state to last for a long time, Θ. Divide this time into n infinitely small parts, ϑ. We shall call the beginning of the first of these parts the time zero; the beginning of the second t_1, the beginning of the third t_2, &c.; the end of the last of the n parts t_n. After the whole time Θ has elapsed, let another series of times of length ϑ begin. Denote the end of the first part after t_n by t_{n+1}; the end of the next following part t_{n+2}, &c. Assume for a moment that we have n separate vessels, all exactly similar to the one containing the gas; that each of these n vessels contains the same gas, and that the motion of the gas is the same in each. The beginning, however, is different. For example, let the gas in the second vessel at time zero be in the same condition in which the gas of the first vessel is at the time t_1; in the third vessel let the gas at the time zero be in exactly the same condition as it is in the first vessel at the time t_2, and so on. We have now in the different vessels all the different states of the gas existing simultaneously which in the first vessel exist successively during the whole time interval Θ.

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[1] 'The Moon's Atmosphere and the Kinetic Theory of Gases,' *Nottingham Report*, 682.

The probability dw that the co-ordinates and momenta of a molecule may lie between the limits

$$a \text{ and } a+da,\ b \text{ and } b+db \ldots p \text{ and } p+dp,\ q \text{ and } q+dq \ldots \qquad (1)$$

can be defined in two ways. If we consider a single *vessel* containing gas, we must observe it for a long time Θ; if τ be the fraction of the time during which the co-ordinates and momenta of a molecule lie between the limits (1)—which we shall call the condition (1)—then τ/Θ is the probability required. The limits (1) differ only infinitesimally from one another. No two molecules of the same gas can be in the condition (1) at the same time. On the other hand, if we consider the above series of n vessels at any single *instant* of time, we can define the probability dw to be dz/n, where dz is the number of vessels in which a molecule is in the condition (1). Evidently dw will have different values for different values of the co-ordinates and momenta. It will also be proportional to the differentials da, db . . . We may therefore put

$$\frac{\tau}{\Theta}=\frac{dz}{n}=dw=f(a, b, \ldots p, q, \ldots)\, da\, db \ldots dp\, dq \ldots \qquad (2)$$

To find the condition for a stationary state we may consider one gas at successive instants, or the series of vessels at one instant. In the first case the values of dw for the stationary state will be the same, whether we consider the gas from time 0 to time t_n, or from time t_1 to time t_{n+1}, or in general from t_k to t_{n+k}. Evidently the converse is true; that is, if dw has the same values for all these cases, the state is stationary. By the second method we must remember that at the time 0 we have in our n vessels all the states which appear in the first case from time 0 to time t_n; at the time t_1 we have in these vessels all the states which appear in the first case from t_1 to t_{n+1}. . . . The above statement, that τ/Θ has the same values in all cases, whether we consider the time from zero to t_n, or from t_1 to t_{n+1}, or from t_k to t_{n+k}, becomes in this second case identical with the statement that dz/n has the same value, whether we consider the n vessels at time zero, or time t_1, or time t_2, &c. That is, since the difference between t_1 and zero, t_2 and t_1 . . . can be made infinitely small, the above statement amounts to saying that for the stationary state dz/n has the same values at all times. We shall next prove that dz/n has this property under the following conditions:—

We define a *free* molecule to be one which is not acted upon by any other molecule. For each free molecule let the values of $f(a, b \ldots p, q \ldots)$

$=He^{-hg}$ at time 0, where g is the total energy of this molecule; H and h are constants; therefore at time 0 the number of vessels in which a free molecule is in the state (1) is

$$n\,dW=nHe^{-hg}da\,db\,\ldots\,dp\,dq\,\ldots\quad.\quad.\quad.\quad(3)$$

Similarly the number of vessels in which a free molecule appears with co-ordinates and momenta between

$$a' \text{ and } a'+da',\ b' \text{ and } b'+db'\ \ldots\ p' \text{ and } p'+dp',\ q' \text{ and } q'+dq'\ \ldots\quad(4)$$

(condition 4) is

$$ndW'=nHe^{-hg'}\,da'db'\,\ldots\,dp'dq'\,\ldots$$

where g' is the total energy of this second free molecule. Finally, the number of vessels in which one free molecule is in condition (1) and a second one in condition (4) is

$$n\,dW\,dW'=nH^2e^{-h(g+g')}\,da\,db\,\ldots\,dp\,dq\,\ldots\,da'db'\,\ldots\,dp'dq'\,\ldots\quad(5)$$

Let a'', b'', . . . a''', b''', . . . be values of the co-ordinates such that a molecule with the former co-ordinates acts on or encounters a molecule with the latter co-ordinates. And let us assume that at the time 0 the number of vessels which contain a pair of molecules whose co-ordinates and momenta respectively lie between

$$\left.\begin{array}{l} a'' \text{ and } a''+da'',\ b'' \text{ and } b''+db'',\ldots p'' \text{ and } p''+dp'',\ q'' \text{ and } q''+dq''\ldots \\ a''' \text{ and } a'''+da''',\ b''' \text{ and } b'''+db''',\ldots p''' \text{ and } p'''+dp''',\ q''' \text{ and } q'''+dq'''\ldots \end{array}\right\}\ (6)$$

is

$$nH^2e^{-hf}\,da''db''\,\ldots\,dp''dq''\,\ldots\,da'''db'''\,\ldots\,dp'''dq'''\,\ldots\quad.\quad(7)$$

where f is the total energy of the two molecules. We proceed to prove that a stationary state is defined by these formulæ. Consider a duration of time t long enough to permit of encounters between a finite number of molecules, but not so long as to permit of many molecules colliding more than once. We must demonstrate that after this time t, the number of vessels in which the state of a molecule lies between certain limits is exactly the same as before this time. We distinguish between four kinds of molecules:—

(i) Molecules which are free at the beginning and at the end, and during the whole time t. For any of these molecules let the co-ordinates and momenta lie at the time 0 between

$$A \text{ and } A+dA,\ B \text{ and } B+dB,\ \ldots\ P \text{ and } P+dP,\ Q \text{ and } Q+dQ\ \ldots\quad(8)$$

and at the time t between

$$a \text{ and } a+da,\ b \text{ and } b+db,\ \ldots\ p \text{ and } p+dp,\ q \text{ and } q+dq\ \ldots\quad.\quad(9)$$

Let G and g represent the energy of such a molecule at the times 0 and t respectively; G, g being equal. According to equation (3) the number of vessels in which at the time 0 the co-ordinates and momenta of a molecule lie between the limits (8) is $nHe^{-hG}dA\,dB,\ldots dP\,dQ.\ldots$ But, by hypothesis, the co-ordinates and momenta of these same molecules lie between the limits (9) at the time t; hence the above expression gives also the number ζ of vessels in which, at the time t, co-ordinates and momenta of a molecule lie between the limits (9). But we have $G=g$, and by a well-known theorem (*cf.* Watson, 'Kinetic Theory of Gases,' 2nd edition, p. 22)

$$da\,db\ldots dp\,dq\ldots = dA\,dB\ldots dP\,dQ$$

Therefore the number ζ is equal to

$$nHe^{-hg}\,da\,db\ldots dp\,dq\ldots$$

But this last expression gives at the time 0 the number of vessels for which the co-ordinates and momenta of a molecule lie between the limits (9) (according to formula 3). We see that this number remains constant during the time t; and since the same is true for all values of a, b, ... p, q, ... the theorem holds good for all molecules of the first kind.

(ii) We call all those molecules 'molecules of the second kind' which are free at the time 0, but which are in process of encounter at the time t. For a pair of such molecules let the co-ordinates and momenta lie at the time 0 between the limits

$$\left.\begin{array}{ll} & A_1 \text{ and } A_1+dA_1,\ B_1 \text{ and } B_1+dB_1 \ldots P_1 \text{ and } P_1+dP_1,\ Q_1 \text{ and } Q_1+dQ_1 \ldots \\ \text{and} & A_2 \text{ and } A_2+dA_2,\ B_2 \text{ and } B_2+dB_2 \ldots P_2 \text{ and } P_2+dP_2,\ Q_2 \text{ and } Q_2+dQ_2 \ldots \end{array}\right\} \quad (10)$$

respectively, and at the time t between the limits

$$\left.\begin{array}{ll} & a_1 \text{ and } a_1+da_1,\ b_1 \text{ and } b_1+db_1 \ldots p_1 \text{ and } p_1+dp_1,\ q_1 \text{ and } q_1+dq_1 \ldots \\ \text{and} & a_2 \text{ and } a_2+da_2,\ b_2 \text{ and } b_2+db_2 \ldots p_2 \text{ and } p_2+dp_2,\ q_2 \text{ and } q_2+dq_2 \ldots \end{array}\right\} . \quad (11)$$

respectively. Because these molecules were free at the time 0, the number of vessels in which at time 0 a pair of molecules fulfils the condition (10) is, according to formula (5),

$$nH^2e^{-h(G_1+G_2)}\,dA_1dB_1\ldots dP_1dQ_1\ldots dA_2dB_2\ldots dP_2dQ_2\ldots$$

G_1 and G_2 are the energies of the molecules at the time 0. But the above-mentioned vessels are identical with the vessels for which at the time t a pair of molecules fulfil the conditions (11). The number of the last kind of vessels is therefore also given by the above expression. It is easily seen that this expression is equal to

$$nH^2e^{-hf}da_1db_1\ldots dp_1dq_1\ldots da_2db_2\ldots dp_2dq_2\ldots$$

where f is the whole energy of the two molecules at time t. Comparison with formula (7) shows that the last formula gives also the number of vessels in which at time 0 a pair of molecules fulfilled the condition (11). Therefore the theorem also holds good for the molecules of the second kind.

(iii) Molecules which are in process of encounter at time 0, but are free at time t;

(iv) Molecules which are free at times 0 and t, but which have been encountered by another molecule between these two instants of time.

It is easily seen that our theorem can be proved in the same way as before for every pair of molecules of the third or fourth kind.

To calculate the mean vis viva $\overline{T}$ of a molecule we put

$$x_1 = k_{11}p + k_{12}q + \ldots,\quad x_2 = k_{21}p + k_{22}q\ldots, \text{ \&c.}$$

The coefficients k may be chosen to be functions of the co-ordinates such that T acquires the form $\frac{1}{2}\,(m_1x_1^2 + m_1x_2^2 + \ldots m_fx_f^2)$, where f is the number of degrees of freedom of a molecule. The probability that for a molecule the co-ordinates and the values of x may lie between a and $a+da$, b and $b+db \ldots x_1$ and x_1+dx_1, x_2 and $x_2+dx_2 \ldots$ is, according to formula (3),

$$He^{-h(V+\frac{1}{2}\Sigma mx^2)}D da\, db \ldots dx_1 dx_2 \ldots$$

where

$$D=\begin{vmatrix} k_{11}, k_{12} \ldots \\ k_{21}, k_{22} \ldots \\ \ldots\ldots \end{vmatrix}$$

It is evident that each momentum, and therefore, also, each of the variables x, can assume all values from $-\infty$ to $+\infty$. We easily obtain the value $1/2h$ for the average value of each term of the form $\frac{1}{2}m_i x_i^2$. Therefore the average vis viva of a molecule is $f/2h$, the average vis viva of the centre of mass of a molecule is $3/2h$, and the ratio of these two quantities is $f : 3$.

The Best Methods of Recording the Direct Intensity of Solar Radiation.—Tenth Report of the Committee, consisting of Sir G. G. STOKES (*Chairman*), Professor A. SCHUSTER, Mr. G. JOHNSTONE STONEY, Sir H. E. ROSCOE, Captain W. DE W. ABNEY, Mr. C. CHREE, Mr. G. J. SYMONS, Mr. W. E. WILSON, *and* Professor H. MCLEOD. (*Drawn up by* Professor MCLEOD.)

VERY little has been done with Balfour Stewart's actinometer during the past year. It will be remembered that in the last Report it was stated that an attempt had been made to replace the thermometer by a thermocouple of copper and iron. From the preliminary experiments it appears that this arrangement is extremely sensitive, and using the instrument as a dynamical actinometer, in which the rate of change of temperature is recorded, a complete observation may be made in from two to three minutes. It was mentioned last year that a D'Arsonval galvanometer had been tried; the Committee have now purchased an Ayrton-Mather galvanometer specially wound for thermo-electric currents: this instrument has been examined by Professor Ayrton, and to him and his pupil, Mr. Arnold Philip, the Committee are indebted for much useful information. The instrument is not yet in a very satisfactory condition, for, in order to make it sufficiently sensitive, the suspending wire has to be unusually fine, and it takes a permanent set, which causes an alteration of zero. Endeavours are being made to overcome this inconvenience. The thermocouple of copper and iron does not give currents quite proportional to the difference of temperature, and it might be preferable to replace the iron by some other metal or alloy. Copper is, of course, one of the essential metals, and it appears difficult to find any other material to replace the iron which will give proportional currents of sufficient strength to be useful.

The Committee ask for reappointment and for the unexpended portion of the grant.

Underground Temperature.—Twentieth Report of the Committee, consisting of Professor J. D. EVERETT, Professor Lord KELVIN, Mr. G. J. SYMONS, Sir A. GEIKIE, Mr. J. GLAISHER, Professor EDWARD HULL, Professor J. PRESTWICH, Dr. C. LE NEVE FOSTER, Professor A. S. HERSCHEL, Professor G. A. LEBOUR, Mr. A. B. WYNNE, Mr. W. GALLOWAY, Mr. JOSEPH DICKINSON, Mr. G. F. DEACON, Mr. E. WETHERED, Mr. A. STRAHAN, *and* Professor MICHIE SMITH. (*Drawn up by* Professor EVERETT, *Secretary.*)

THE Committee were appointed for the purpose of investigating the rate of increase of underground temperature downwards in various localities of dry land and under water.

The nineteenth Report contained the results of observations taken in 1891 by Mr. Hallock, of the Smithsonian Institution, at depths extending to 4,462 feet in a nearly dry well at Wheeling, Virginia.

Mr. Hallock, who now dates from Columbia College, New York, has recently furnished the Secretary with printed copies of a paper, contributed by him to the American Association for the Advancement of Science last year, containing further observations in the well, made at the expense of the U.S. Geological Survey.

When the observations of 1891 were finished, an oak plug was driven into the top of the casing to protect the hole. In July 1893 the plug was withdrawn, and the well, instead of being dry as before, was found to be full of fresh water to within 40 feet of the top. This water is believed to have leaked in at the lower end of the innermost casing—that is, at 1,570 feet below the surface.

By means of inverted Negretti maximum thermometers, protected against pressure by sealing them in stout glass tubes, careful observations were taken at various depths from 1,586 feet to 3,196 feet, two thermometers being employed to check one another at each depth. The results were practically identical with those obtained two years previously, when the well was full of air, the greatest certain difference being only one-fifth of a degree. An obstruction at 3,200 feet prevented observation at greater depths; but this obstruction will probably be removed, the well pumped dry, and the drilling continued.

In making the observations, four thermometers were lowered at a time, two of them being in an iron bucket 3 feet long and 3 inches in diameter at the end of the wire, and the other two in an open wire frame 260 feet from the end of the wire, the diameter of the bore being just under 5 inches.

The temperatures at 103 feet, 206 feet, and 300 feet were also observed with suitable thermometers, the temperature at 103 feet being 52°·53, which is 1°·2 higher than the true temperature of the soil at that depth, as determined by other observations in the immediate neighbourhood.

The smallness of the disturbance of temperature by convective circulation in this well, both when dry and when filled with water, is very remarkable, and renders the well specially suitable for determinations of the increase of temperature downwards.

The Committee have to record with deep regret the loss of their valuable member, Mr. Pengelly.

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLAREN (*Chairman*), Professor A. CRUM BROWN (*Secretary*), Dr. JOHN MURRAY, Dr. ALEXANDER BUCHAN, Hon. RALPH ABERCROMBIE, *and* Professor COPELAND. (*Drawn up by* Dr. BUCHAN.)

THE Committee were appointed as in former years for the purpose of co-operating with the Scottish Meteorological Society in making observations on Ben Nevis at the two observatories situated respectively at the top and bottom of the mountain.

During the year the hourly eye observations by night and by day have been uninterruptedly made by Mr. Omond and his assistants; and the continuous registrations and other observations have been carried on at the Low Level Observatory at Fort William with a like fulness of detail as in previous years.

Owing to frequent storms and heavy snowfalls, which lay long and deep, the climatic conditions at the top of the mountain were very severe; but the Directors have the greatest satisfaction in reporting that the health of the observers has notwithstanding been good. The Directors tender their best thanks to Messrs. Charles Stewart, B.Sc., Craig, Shand, Herbertson, and Rankin.

TABLE I.—*Showing Monthly Mean and Extreme Pressures, Temperatures, Rainfall, Sunshine, and Clouds.*

1893	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Mean Pressure in Inches.													
Ben Nevis Observatory	25·336	24·936	25·373	25·580	25·493	25·491	25·377	25·437	25·225	25·171	25·360	25·101	25·324
Fort William	29·991	29·503	29·972	30·151	30·018	29·974	29·842	29·902	29·718	29·699	30·004	29·682	29·871
Differences .	4·655	4·567	4·599	4·571	4·525	4·483	4·465	4·465	4·493	4·528	4·644	4·581	4·547
Mean Temperatures.													
Ben Nevis Observatory	23°·2	23°·8	28°·5	34°·9	37°·4	42°·5	42°·0	43°·6	36°·1	31°·8	25°·8	26°·7	33°·0
Fort William	37·6	39·9	43·5	49·2	53·6	57·5	59·0	59·5	52·6	47·7	39·1	42·4	48·5
Differences .	14·4	16·1	15·0	14·3	16·2	15·0	17·0	15·9	16·5	15·9	13·3	15·7	15·5
Extremes of Temperature, Maxima.													
Ben Nevis Observatory	35°·7	34°·9	39°·9	52°·5	52°·1	62°·6	57°·2	62°·2	57°·3	48°·0	39°·2	37°·6	62°·6
Fort William	52·1	55·0	60·8	71·3	69·8	74·1	79·3	83·2	68·7	58·4	53·8	53·5	83·2
Differences .	16·4	20·1	20·9	18·8	17·7	11·5	22·1	21·0	11·4	10·4	14·6	15·9	20·6
Extremes of Temperature, Minima.													
Ben Nevis Observatory	6°·4	13°·0	10°·3	20°·2	22°·7	29°·8	33°·1	32°·0	18°·4	17°·0	10°·2	7°·2	6°·4
Fort William	13·9	24·8	25·0	32·7	36·0	41·2	42·0	41·3	32·0	32·8	26·5	21·6	13·9
Differences .	7·5	11·8	14·7	12·5	13·3	11·4	8·9	9·3	13·6	15·8	16·3	14·4	7·5
Rainfall in Inches.													
Ben Nevis Observatory	12·23	10·33	12·57	5·99	5·48	5·88	12·32	14·79	19·25	22·84	18·43	25·66	165·77
Fort William	5·40	8·47	4·44	3·12	2·73	1·89	3·95	6·55	9·35	12·75	8·03	16·86	83·54
Differences .	6·83	1·86	8·13	2·87	2·75	3·99	8·37	8·24	9·90	10·09	10·40	8·80	82·23

TABLE I.—*continued.*

1893	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Number of Days of no Rain.							
Ben Nevis Observatory	6	5	11	14	11	13	10	4	4	0	11	0	89
Fort William	9	10	11	16	16	18	12	9	9	3	15	2	120
						Number of Days 1 in. or more fell.							
Ben Nevis Observatory	3	4	3	1	1	1	3	3	7	7	6	12	51
Fort William	1	2	0	0	0	0	0	1	2	1	2	3	12
						Hours of Sunshine.							
Ben Nevis Observatory	29	15	83	151	73	134	57	34	39	14	50	1	680
Fort William	25	54	107	174	128	186	110	92	108	45	30	6	1,065
Differences .	−4	39	24	23	55	52	53	58	69	31	−20	5	385
						Percentage of Cloud.							
Ben Nevis Observatory	87	92	75	61	88	74	92	92	88	95	71	98	84
Fort William	68	82	74	56	68	60	82	80	68	80	68	84	72
Differences .	19	10	1	5	20	14	10	12	20	15	3	14	12

For the year 1893 Table I. gives the monthly mean and extreme pressures, temperatures, hours of sunshine, amounts of clouds and rainfall, and number of days of no rain on the one hand, and on the other of days when the rainfall was not less than one inch at the two observatories, the mean pressures at the top being reduced to 32° only, while those at Fort William are reduced to 32° and sea level.

The mean temperature of the year at Fort William was 48°·5, being 3°·2 greater than that of the previous year, and 1°·3 in excess of the mean annual temperature of the place. The mean at the top of the mountain was 33°·0, which is 3°·3 in excess of the previous year and 2°·2 greater than the mean annual temperature deduced from all the observations made since 1881. The following show the deviations of the monthly results from their respective means :—

	Top of Ben Nevis	Fort William
	°	°
January	−1·5	−1·7
February	−0·1	+0·7
March	+5·9	+3·5
April	+8·6	+3·8
May	+5·2	+3·6
June	+4·0	+1·7
July	+1·9	+1·7
August	+4·1	+2·5
September	−1·6	−0·6
October	+0·3	−0·1
November	−2·2	−2·6
December	+2·0	+2·4
Year	+2·2	+1·3

Thus the outstanding feature of the meteorology of the year was the abnormally high temperature which prevailed during the six months from March to August. The mean temperature at the top for the six months was then 5° above the mean, whilst at Fort William it was only 2°·8, or but little more than half the excess at the top of the mountain. The reason for this extraordinary difference is the remarkable and prolonged continuance of anti-cyclonic weather during the time when, as has been often referred to in ~~our Reports to the British Association,~~ ~~the~~ ~~tempe-~~ rature at the top is frequently much higher, absolutely, than it is at Fort William.

The lowest mean monthly temperature at Fort William was 37°·6, for January, and at the top 23°·2 in the same month, these being respectively 1°·7 and 1°·5 under the average of the month. The warmest month was August at both stations, where the means were 59°·5 and 43°·6, or 2°·5 and 4°·1 in excess of their averages.

The maximum temperature at the top was 62°·6 on June 18, and at Fort William 83°·2 on August 9. The minimum at the top was 6°·4 on January 2, and at Fort William 13°·9 on January 6 As compared with previous years the minima for the five months from April to August were relatively high reading at both stations, showing that the temperature was during these months not only high as regards the means, but was marked by a singular absence of such low temperatures as usually occur.

At the top the registrations of the sunshine recorder show 680 hours out of a possible 4,470 hours, being 122 hours fewer than during the previous year, and 228 fewer than during 1891. The following months exceeded the averages : March by 20 hours, April by 60 hours, November by 23 hours, and January by 6 hours. The maximum was 151 hours in April, and this is also longer than any previous recorded April. All other months fell short of the averages, and during the whole of December only one hour's sunshine was recorded, and on the following month, viz., January 1894, only three hours' sunshine occurred. At Fort William the number of hours of sunshine were 1,065, which is respectively 114 and 155 hours fewer than during the previous two years. The maximum was 186 hours in June, and the minimum 6 hours in December. At these stations, in common with a large surrounding district, 1894 was characterised by a singular deficiency of sunshine, which is remarkable in view of the high temperature of the year. At the top of the mountain the proportion of the actual to the possible sunshine was only 15 per cent., and at Fort William the percentage was 30, or double that at the top.

At the top the percentage of cloud covering the sky was 84, being the average of previous years. It varied greatly in the different months, being above 90 per cent. in February, July, August, October, and December, which were characterised by a marked deficiency of sunshine, and reached 98 per cent. in December, when, as already stated, only one hour of sunshine was recorded. On the other hand, the minimum 61 per cent. occurred in April, the month of the absolute maximum sunshine, being 66 per cent. above the maximum of the month.

The following table shows the lowest humidities of each month :—

TABLE II.—*Lowest Hygrometric Readings each Month.*

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb . . .	° 24·6	° 22·8	° 14·8	° 35·2	° 32·8	° 48·1	° 52·3	° 47·1	° 51·6	° 37·7	° 27·8	° 17·0
Wet Bulb . .	19·1	20·6	12·0	25·4	26·2	35·9	42·6	33·6	37·2	29·0	22·2	14·6
Dew-point . .	−12·2	6·5	−9·8	9·7	12·3	22·5	32·8	18·7	22·8	16·8	−1·3	−3·6
Elastic Force . .	·024	·058	·026	·067	·075	·120	·186	·101	·132	·093	·041	·037
Relative Humidity	18	47	31	33	40	36	47	31	32	41	27	39

As compared with the similar table in last year's Report the following results are interesting for 1892 and 1893: Lowest dew-point, −27°·8 and −12°·2, highest dew-point 21°·2 and 32°·8; lowest elastic force 0·010 inch and 0·024 inch; highest elastic force 0·114 inch and 0·122 inch; and lowest relative humidity 7 and 18, and highest 47 and 47. These results point to a large excess of aqueous vapour in the air at the Ben Nevis Observatory during 1893.

The rainfall for the year at the top was 165·77 inches, being 18·00 inches above the mean annual rainfall. At Fort William the amount was 83·54 inches, which is 10·37 inches above the mean. These amounts are respectively 12 and 14 per cent. above their averages. The maximum monthly rainfall at the Ben Nevis Observatory was 25·66 inches, in December, and the minimum 5·48 inches, in May. The minimum monthly fall for 1892 was 5·42 inches in March, and these two years show the largest minimum falls of any of the years since the Observatory was opened. Hence, at this high level situation the rainfall was not only considerably above the mean, but it continued to be relatively large through all the months of this year, which will be long remarkable for an unprecedented drought over a large portion of the British Islands. On the other hand, at the Low Level Observatory the amount of the rainfall was short of the average for each of the five months from March to July, the deficiency amounting to 5·12 inches.

At Fort William the rain fell on 235 days, and at the top on 260 days, being respectively 3 days under and 26 days above their averages. The maximum number of days on which rain fell was 31 days at the top and 29 at Fort William in December, and the minimum number 16 days in March and 12 days in June respectively.

The maximum daily rainfall at the top was 4·29 inches on November 28, and at Fort William 3·25 inches on October 24. At the former station instances of one inch a day or upwards occurred during each of the twelve months, whereas at Fort William, during the five months from March to July, the rainfall on none of the days reached an inch. During the year the rainfall amounted to an inch or upwards on 51 days, but at Fort William the number of days was only 12, being a lower proportion at Fort William, as compared with the top, than has previously been recorded. Thus, while during the spring and early summer of 1893 Fort William participated in some degree in the prevailing drought, the rainfall and moisture at the Ben Nevis Observatory were above their average, a result probably occasioned by the stronger ascending currents from the superheated surface of the earth carrying to higher levels than usual the moisture of lower levels.

Auroras are reported to have been observed on the following dates:—January 5, 9, 10, and 11; February 15; March 26 and 29; April 3, 11, 12, 26, and 27; May 9; August 12; September 11; October 4 and 17; and November 8, 9, 10, 11, 12, 13, and 14.

St. Elmo's Fire was seen on February 9; April 6 and 20; August 15; October 25; and December 8.

Thunderstorms occurred on April 6; May 19 and 21; June 8, 12, and 13; July 7, 8, 10, and 11; August 15; September 8; and December 11. On May 21 the thunderstorm passed below the level of the summit, being very severe, with much lightning and exceptionally heavy rain and hail at Fort William, while on the summit there was no lightning and only a slight shower of rain. On June 13 the thundercloud enveloped the summit for some time, and the lightning, entering the Observatory, damaged the telegraph cable, and greatly interrupted communication during the rest of the month, so that on several nights the usual daily weather report could not be wired to the newspapers. The thunderstorm of July 7–8, though very severe, was fortunately unaccompanied by any damage.

At Fort William the mean atmospheric pressure at 32° and sea level was 29·871 inches, and at the top 25·324 inches, the difference being thus 4·547 inches. The lowest pressure at the top for the year was 23·888 inches in December and the highest 26·003 inches in April, the difference being 2·115 inches, being considerably above the average difference. This large difference was due to the low reading in December, which was an altogether exceptional month as regards the almost continuous saturated state of the atmosphere, and to the high readings which accompanied the anticyclonic weather of the spring and early summer. In truth, the monthly means were uninterruptedly above the average for the six months from March to August, the mean excess for the half-year being so much as 0·101 inch above the average, an excess only exceeded in 1887, the Jubilee year, when the mean monthly pressure was uninterruptedly above the average from February to July, the mean excess being 0·144 inch. This period was also strongly anticyclonic.

The important hygrometric research carried on at the High and Low Level Observatories and described in the Committee's last two Reports to the British Association has been continued. During the past year Mr. Herbertson has conducted the observations with the assistance of Mr. Angus Rankin, First Assistant at the Observatories, and of Mr. F. J. Hambly, F.C.S., F.I.C., Assistant Lecturer on Chemistry at University College, Dundee; and of Mr. Marr, Demonstrator of Botany in the same College.

An Assmann aspiration psychrometer was read for dry and wet bulb temperatures, in addition to the thermometers in the Stevenson screen. The dust particles in the air were counted, and the general weather conditions of each experiment were noted. Nearly 100 experiments were made at both observatories, of which 57 were synchronous.

A comparison of the readings of the ventilated thermometers with those of the screen only shows that in calm, or virtually calm, weather the wet-bulb in the Stevenson box is much nearer the dry-bulb reading than in the Assmann aspiration psychrometer. When no measures are taken for causing an air current to pass the thermometer bulbs, all readings made in calm or light airs require to be neglected in hygrometric work. Under ordinary conditions, the total amount of water vapour in the air does not vary much in a fine day.

A discussion of the simultaneous observations at high- and low-levels brings out some very interesting results. On September 11, 1893, with a normal temperature gradient between the two observatories, the water-vapour remained fairly constant at both places all day, there being an excess of about 1·5 gramme per cubic metre at the lower station. On September 4 the summit temperature was only from 2° to 7° lower than at Fort William, instead of 16°·0 the normal difference; and on this occasion the difference between the quantities of water-vapour was as great as from 6·[illegible]7 to 4·60 grammes per cubic metre. This great variation was almost entirely due to changes in the amount of water-vapour in the upper air, since there was a steady increase of vapour from 9·15 grammes per cubic metre at 9 A.M. to 10·56 at 2 P.M., and 11·40 at 7 P.M. at the low-level station; whereas the vapour at the summit was 2·72 at 9 A.M., 5·96 at 2 P.M., 3·92 at 5 P.M., 5·55 at 7 P.M., and 5·89 at 9 P.M.; the maximum at the summit at 2 P.M. being evidently caused by an uprush of moister air from the valleys. Thin cirrus clouds floated above the hill all day, and detached masses of fog were in the valleys. The next day the hill-top was enveloped in mist, and thick cumulus clouds were observed over Fort William with a smaller hourly variation both of temperature and water-vapour.

Mr. Marr continued the work at Fort William at Christmas, and Mr. Herbertson in May, the latter having carried on the experiments in the drier air of Montpellier during the early months of this year. These data have served to extend the curves drawn from the figures already obtained, the Montpellier results being found to agree well with those made at Fort William where they overlapped.

It is Mr. Herbertson's intention to continue these investigations in the coming autumn and winter, more special attention being then given to secure an increased number of simultaneous high and low determinations of water-vapour.

The inquiry into the hourly variation of pressure and temperature at the observatories during days of clear weather on the one hand, and days of fog or mist throughout on the other, has been prosecuted during the year. On completing the hourly variations of pressure during each of these two distinct types of weather at the Low Level Observatory at Fort William on the same days at the top of the mountain, it was seen that substantially the same sets of curves obtained in both situations. In particular at both places the same extraordinarily high pressure from about 6 P.M. to 2 A.M. occurs during days of fog or mist, or completely clouded days, thus demonstrating the important *rôle* played by the aqueous vapour of the atmosphere in the diurnal meteorological changes. The point was considered to be of such importance as to warrant the extension of the inquiry to another place where the climate, as regards moisture, resembles in some degree that of Fort William. Trieste, at the head of the Adriatic Sea, was selected for examination, particularly since the hourly values for pressure and sunshine are published for this place. The results for the three observatories are given in Tables III. to VIII. of this Report. The times over which the inquiry extends are three years, from August 1890 to July 1892 for the Ben Nevis Observatories, and the three years 1888 to 1890 for Trieste. The results have been 'bloxamed,' as explained in our last Report (p. 284).

The results of the investigation, so far as it has been carried, are, broadly stated, these :—During fine cloudless weather the hourly curves of the three places are virtually congruent with their curves for the whole of the observations, clear and clouded alike, except that the diurnal phases of maxima and minima are more strongly pronounced, and the evening maximum is continued for a shorter period. During foggy and clouded weather each of the three places shows in the colder months of the year the ordinary double maxima and minima of pressure fairly well marked. It is quite otherwise in the warmer months, when at the Ben Nevis Observatories the morning maximum is virtually obliterated, and Trieste very greatly reduced. It is, however, the evening maximum which shows the most surprising results. This is at all seasons at the low-level stations, but in the warmer months it is the outstanding feature of the curves. For May, June, and July the mean at the top is 0·018 inch, at Fort William 0·023 inch, and at Trieste also 0·023 inch. In these months the maximum of this phase of the barometric curve occurred either at midnight or shortly before it.

The temperature curves for the Ben Nevis Observatory have also been calculated, with the result that on clear days the diurnal range of temperature is only very slightly in excess of that of foggy days. But in summer the difference between the mean coldest and warmest hour is 1°·1; but on clear days the difference is 2°·9, or nearly three times greater.

The further prosecution of this inquiry and examination of the cyclones and anti-cyclones of North-Western Europe will engage the attention of your Committee next year, when a large portion of the time of Dr. Buchan and Mr. Omond will be given to this work.

TABLE III.—*Showing at the Ben Nevis Observatory the Mean Hourly Variation of Pressure, in thousandths of an inch, during clear days. The minus sign means under the average.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	−13	−10	−8	−7	−7	−9	−10	−11	−13	−16	−17	−17	−12
2 ,,	−15	−12	−10	−10	−11	−12	−13	−13	−14	−16	−17	−18	−13
3 ,,	−14	−13	−14	−14	−15	−6	−18	−16	−16	−17	−18	−17	−16
4 ,,	−16	−15	−16	−17	−18	−17	−20	−18	−17	−17	−18	−18	−17
5 ,,	−16	−14	−15	−17	−18	−17	−19	−17	−16	−15	−18	−19	−17
6 ,,	−11	−9	−10	−13	−13	−13	−16	−14	−12	−12	−15	−15	−12
7 ,,	−6	−6	−7	−9	−9	−9	−11	−9	−7	−6	−8	−9	−8
8 ,,	−0	−1	−1	−3	−4	−5	−6	−3	+1	+4	+3	+1	−1
9 ,,	+10	+6	+5	+1	+0	+0	−1	+2	+6	+11	+12	+11	+5
10 ,,	+14	+10	+9	+5	+4	+3	+3	+6	+9	+15	+18	+16	+9
11 ,,	+17	+13	+12	+9	+7	+6	+7	+9	+12	+18	+22	+21	+13
Noon	+15	+13	+14	+12	+11	+11	+11	+13	+15	+20	+22	+19	+15
1 P.M.	+12	+12	+14	+14	+12	+12	+13	+15	+16	+18	+17	+14	+14
2 ,,	+8	+8	+10	+13	+13	+14	+14	+14	+12	+13	+13	+11	+12
3 ,,	+5	+5	+5	+9	+11	+13	+13	+13	+11	+9	+8	+7	+9
4 ,,	+4	+3	+2	+6	+8	+11	+11	+10	+6	+5	+6	+7	+7
5 ,,	+5	+5	+3	+5	+6	+8	+10	+8	+5	+5	+6	+8	+6
6 ,,	+7	+6	+4	+4	+4	+6	+8	+6	+5	+4	+7	+9	+6
7 ,,	+7	+6	+4	+4	+3	+4	+7	+6	+5	+4	+6	+8	+5
8 ,,	+6	+5	+4	+5	+5	+5	+7	+7	+5	+3	+4	+6	+5
9 ,,	+4	+3	+3	+5	+6	+7	+8	+6	+2	−3	−0	+3	+4
10 ,,	+0	+0	+1	+3	+4	+5	+6	+2	−2	−7	−4	−2	+1
11 ,,	−5	−4	−2	−0	−0	+1	+1	−2	−8	−13	−11	−9	−4
Midnight	−11	−9	−5	−4	−5	−5	−5	−7	−12	−16	−15	−14	−9

TABLE IV.—*Showing at the Ben Nevis Observatory the Mean Hourly Variation of Pressure, in thousandths of an inch, during days of fog or mist. The minus sign shows the means under the average.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+4	+8	+6	+8	+7	+10	+7	+6	+4	+8	+6	+6	+7
2 ,,	+0	+1	−2	−2	−4	−1	−2	−0	−3	−0	−1	+2	−1
3 ,,	−3	−6	−10	−11	−11	−9	−10	−8	−10	−5	−5	−1	−8
4 ,,	−9	−12	−14	−17	−17	−16	−16	−15	−15	−9	−8	−7	−15
5 ,,	−11	−14	−15	−21	−20	−20	−20	−18	−16	−10	−9	−11	−15
6 ,,	−15	−18	−16	−20	−20	−20	−19	−17	−16	−11	−10	−13	−16
7 ,,	−14	−16	−13	−17	−17	−18	−17	−16	−14	−8	−8	−11	−14
8 ,,	−9	−10	−7	−11	−12	−15	−14	−13	−10	−3	−2	−6	−9
9 ,,	−5	−8	−4	−9	−10	−13	−11	−11	−8	−1	+3	−1	−7
10 ,,	−1	−4	−0	−5	−6	−10	−8	−8	−6	−1	+3	+1	−4
11 ,,	+3	+0	+3	−2	−3	−7	−4	−4	−3	−1	+3	+3	−1
Noon	+4	+2	+5	+0	−1	−4	−0	−1	−0	−2	+0	+1	+1
1 P.M.	−0	−1	+3	+3	+3	+1	+3	+4	+1	−5	−4	−4	+1
2 ,,	−3	−4	+1	+4	+5	+4	+4	+4	+1	−7	−6	−7	−1
3 ,,	−4	−5	−0	+4	+6	+3	+5	+3	+0	−8	−8	−8	−1
4 ,,	−2	−4	−3	+2	+6	+7	+7	+4	+1	−8	−7	−6	+0
5 ,,	+1	+1	+0	+2	+5	+6	+6	+4	+3	−4	−5	−4	+2
6 ,,	+4	+5	+2	+4	+7	+9	+7	+5	+4	−1	−2	−1	+4
7 ,,	+8	+9	+5	+8	+10	+14	+12	+10	+9	+4	+4	+4	+8
8 ,,	+11	+12	+9	+12	+13	+16	+15	+15	+13	+8	+7	+8	+12
9 ,,	+12	+14	+10	+14	+15	+20	+19	+18	+16	+13	+11	+12	+14
10 ,,	+11	+14	+10	+15	+16	+23	+21	+20	+17	+15	+12	+13	+16
11 ,,	+10	+14	+10	+15	+16	+22	+21	+20	+16	+15	+12	+12	+15
Midnight	+10	+15	+11	+15	+14	+22	+19	+18	+13	+14	+11	+13	+15

Table V.—*Showing at Fort William Observatory the Mean Hourly Variation of Pressure, in thousandths of an inch, during clear days. The minus sign shows means under the average.*

Hour	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	−14	− 7	− 0	+ 6	+ 7	+ 6	+ 3	− 3	− 9	−16	−20	−19	− 6
2 "	−13	− 6	− 0	+ 6	+ 8	+ 6	+ 3	− 2	− 6	−12	−17	−17	− 4
3 "	−14	− 8	− 3	+ 3	+ 6	+ 6	+ 2	− 2	− 8	−14	−18	−18	− 6
4 "	−15	− 7	+ 1	+ 5	+ 8	+ 7	+ 3	− 1	− 6	−11	−17	−18	− 4
5 "	−15	− 6	− 0	+ 7	+10	+ 9	+ 4	− 1	− 4	− 8	−16	−18	− 3
6 "	− 9	− 2	+ 7	+13	+17	+16	+11	+ 8	+ 4	− 0	− 9	−12	+ 4
7 "	− 2	+ 3	+11	+16	+19	+17	+13	+12	+10	+ 6	− 1	− 5	+ 8
8 "	+ 9	+12	+18	+18	+20	+18	+16	+18	+19	+18	+13	+10	+16
9 "	+16	+15	+18	+16	+16	+15	+14	+17	+20	+23	+21	+17	+17
10 "	+22	+18	+18	+14	+11	+11	+12	+16	+19	+26	+28	+24	+18
11 "	+26	+17	+14	+ 7	+ 3	+ 4	+ 5	+ 9	+14	+23	+29	+26	+15
Noon	+21	+12	+ 9	+ 2	− 2	− 0	+ 2	+ 6	+11	+19	+24	+25	+11
1 P.M.	+10	+ 4	− 0	− 6	−10	− 8	− 5	− 1	+ 3	+11	+16	+14	+ 2
2 "	+ 6	− 2	− 8	−12	−14	−12	− 9	− 5	− 2	+ 4	+ 7	+ 7	− 3
3 "	− 3	− 7	−15	−19	−20	−16	−14	−12	− 9	− 4	− 1	+ 2	−10
4 "	− 2	− 8	−18	−22	−23	−20	−17	−15	−12	− 6	− 1	+ 3	−12
5 "	− 1	− 9	−19	−24	−25	−23	−19	−18	−15	− 9	− 1	+ 4	−13
6 "	+ 5	− 8	−13	−19	−21	−20	−16	−15	−10	− 5	+ 3	+ 7	− 9
7 "	+ 4	− 1	− 9	−14	−17	−17	−13	−11	− 7	− 4	+ 2	+ 6	− 6
8 "	+ 5	+ 2	− 2	− 5	− 7	− 7	− 5	− 2	− 0	− 1	+ 2	+ 5	− 1
9 "	+ 0	− 1	− 1	+ 1	+ 1	+ 0	+ 1	+ 0	− 1	− 4	− 3	− 1	− 1
10 "	− 2	− 1	+ 1	+ 4	+ 6	+ 5	+ 5	+ 2	− 2	− 8	− 8	− 5	− 0
11 "	− 8	− 4	− 2	+ 4	+ 6	+ 6	+ 5	+ 0	− 6	−15	−15	−11	− 3
Midnight	−12	− 6	− 1	+ 5	+ 7	+ 6	+ 4	− 3	−10	−19	−21	−18	− 6

Table VI.—*Showing at Fort William Observatory the Mean Hourly Variation of Pressure, in thousandths of an inch, during days of fog or mist. The minus sign shows means under the average.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+ 9	+13	+11	+14	+15	+16	+12	+10	+ 9	+11	+ 9	+11	+12
2 "	+ 6	+ 9	+ 5	+ 7	+ 7	+ 8	+ 4	+ 3	+ 1	+ 5	+ 4	+ 8	+ 6
3 "	− 2	− 2	− 6	− 5	− 5	− 4	− 6	− 6	− 8	− 4	− 3	+ 1	− 4
4 "	− 7	− 7	− 8	−10	− 9	−10	−12	−12	−12	− 6	− 6	− 4	− 9
5 "	−10	−10	− 9	−14	−14	−15	−15	−16	−16	−10	− 9	− 9	−12
6 "	−12	−13	− 9	−11	−11	−13	−13	−14	−13	− 8	− 6	− 8	−11
7 "	−13	−13	− 8	−11	−11	−13	−12	−12	−11	− 7	− 7	−10	−11
8 "	− 9	−10	− 3	− 6	− 7	−10	− 9	− 9	− 7	− 2	− 0	− 5	− 6
9 "	− 6	− 8	− 2	− 5	− 8	−12	−10	− 9	− 8	− 1	+ 2	− 2	− 6
10 "	+ 2	− 1	+ 4	− 3	− 7	−12	− 9	− 6	− 5	+ 2	+ 6	+ 5	− 2
11 "	+ 4	− 1	+ 1	− 6	− 8	−11	− 8	− 7	− 7	− 2	+ 5	+ 6	− 3
Noon	+ 1	− 2	+ 1	− 4	− 6	− 8	− 5	− 3	− 5	− 4	+ 0	+ 1	− 3
1 P.M.	− 4	− 8	− 4	− 7	− 6	− 7	− 4	− 4	− 6	− 8	− 5	− 6	− 6
2 "	− 9	−11	− 7	− 5	− 4	− 5	− 2	− 3	− 4	−10	− 8	−10	− 7
3 "	−11	−12	−13	−10	− 8	− 7	− 5	− 6	− 6	−12	−12	−12	−10
4 "	− 7	−10	−12	− 9	− 8	− 7	− 4	− 4	− 4	−10	− 8	− 7	− 8
5 "	− 3	− 5	− 8	− 8	− 6	− 4	− 4	− 4	− 3	− 7	− 6	− 6	− 5
6 "	+ 3	+ 2	− 1	− 1	− 1	+ 1	+ 0	+ 1	+ 4	+ 1	+ 0	− 1	+ 1
7 "	+ 6	+ 5	+ 2	+ 2	+ 3	+ 4	+ 3	+ 5	+ 8	+ 4	+ 3	+ 1	+ 4
8 "	+ 9	+11	+10	+11	+11	+12	+11	+13	+17	+11	+ 7	+ 5	+11
9 "	+10	+12	+10	+15	+17	+19	+17	+17	+18	+12	+ 8	+ 7	+14
10 "	+12	+16	+15	+20	+22	+24	+22	+22	+21	+16	+10	+11	+18
11 "	+11	+13	+14	+19	+21	+24	+23	+20	+19	+16	+11	+12	+17
Midnight	+15	+22	+19	+23	+22	+25	+22	+19	+17	+18	+13	+17	+19

TABLE VII.—*Showing at Trieste the Mean Hourly Variation of Pressure, in thousandths of an inch, during clear days. The minus sign shows means under the average.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+ 6	+ 5	+ 2	− 1	+ 0	+ 1	+ 0	+ 1	+ 1	+ 6	+ 5	+ 6	+ 3
2 ,,	+ 6	+ 6	+ 2	− 2	− 2	− 1	− 2	− 0	− 0	+ 4	+ 3	+ 5	+ 2
3 ,,	+ 4	+ 4	+ 0	− 3	− 4	− 4	− 5	− 3	− 4	− 1	− 0	+ 4	− 1
4 ,,	+ 1	+ 2	− 3	− 5	− 6	− 6	− 6	− 5	− 5	− 2	− 2	+ 1	− 3
5 ,,	− 2	− 0	− 4	− 5	− 6	− 4	− 3	− 4	− 4	− 3	− 4	− 2	− 3
6 ,,	− 2	− 0	− 1	− 1	− 1	+ 1	+ 0	− 2	− 1	− 2	− 3	− 3	− 1
7 ,,	+ 0	+ 4	+ 6	+ 7	+ 7	+ 7	+ 6	+ 4	+ 5	+ 3	+ 1	− 1	+ 4
8 ,,	+ 4	+ 9	+13	+12	+15	+12	+12	+10	+11	+10	+ 8	+ 5	+10
9 ,,	+10	+14	+16	+19	+17	+16	+16	+16	+17	+16	+15	+12	+15
10 ,,	+11	+14	+15	+18	+16	+16	+16	+16	+16	+14	+13	+11	+15
11 ,,	+ 8	+11	+13	+15	+15	+15	+15	+13	+13	+11	+10	+ 8	+12
Noon	+ 2	+ 7	+10	+12	+11	+12	+12	+ 9	+ 8	+ 4	+ 3	+ 0	+ 8
1 P.M.	− 8	− 5	+ 1	+ 5	+ 6	+ 5	+ 6	+ 3	+ 1	− 3	− 6	− 9	− 0
2 ,,	−16	−14	− 7	− 3	− 0	− 0	+ 1	− 2	− 6	−11	−13	− 6	− 7
3 ,,	−16	−17	−11	− 9	− 6	− 5	− 3	− 6	−11	−16	−15	−17	−11
4 ,,	−15	−18	−15	−14	−11	−11	−10	−12	−16	−19	−16	−17	−14
5 ,,	−13	−18	−16	−17	−16	−17	−15	−16	−17	−18	−15	−14	−16
6 ,,	− 9	−14	−15	−18	−18	−19	−19	−18	−15	−14	−10	−10	−15
7 ,,	− 3	− 8	− 9	−12	−13	−16	−17	−15	−11	− 7	− 4	− 4	−10
8 ,,	+ 1	− 3	− 4	− 6	− 8	−11	−11	− 7	− 3	− 1	+ 1	+ 2	− 4
9 ,,	+ 6	+ 4	+ 2	+ 1	+ 0	− 2	− 2	+ 2	+ 4	+ 6	+ 6	+ 7	+ 3
10 ,,	+ 8	+ 6	+ 3	+ 3	+ 3	+ 2	+ 2	+ 5	+ 6	+ 8	+ 8	+ 9	+ 5
11 ,,	+ 9	+ 7	+ 3	+ 2	+ 3	+ 4	+ 3	+ 5	+ 4	+ 7	+ 8	+11	+ 5
Midnight	+ 7	+ 4	+ 0	− 1	+ 1	+ 3	+ 2	+ 4	+ 2	+ 6	+ 6	+10	+ 4

TABLE VIII.—*Showing at Trieste the Mean Hourly Variation of Pressure, in thousandths of an inch, during completely clouded days. The minus sign indicates means above the average.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+ 9	+11	+14	+18	+21	+15	+ 5	− 1	+ 6	+15	+16	+13	+12
2 ,,	+ 7	+ 8	+ 8	+10	+10	+ 4	− 2	− 7	+ 1	+ 8	+12	+10	+ 6
3 ,,	+ 6	+ 3	− 1	− 3	− 2	− 6	−10	−13	− 7	+ 1	+ 6	+ 8	− 2
4 ,,	− 1	− 3	− 8	−10	− 9	−12	−16	−19	−16	− 8	− 4	− 0	− 9
5 ,,	− 6	− 7	−15	−17	−14	−13	−13	−18	−15	−13	− 9	− 5	−12
6 ,,	− 8	−10	−17	−19	−15	−14	−11	−15	−13	−15	−13	− 8	−13
7 ,,	− 6	− 9	−15	−17	−13	− 9	− 8	− 6	−10	−14	−12	− 7	−10
8 ,,	− 0	− 1	− 8	−11	− 8	− 4	− 2	− 3	− 5	− 6	− 6	− 1	− 5
9 ,,	+ 7	+ 6	− 1	− 4	− 1	+ 4	+12	+10	+ 7	− 2	− 2	+ 4	+ 3
10 ,,	+10	+10	+ 2	− 1	− 0	+ 4	+15	+15	+13	+ 2	+ 1	+ 6	+ 7
11 ,,	+ 8	+10	+ 4	− 1	− 3	+ 1	+16	+20	+18	+ 2	− 1	+ 2	+ 6
Noon	+ 0	+ 4	+ 0	− 3	− 7	+ 0	+ 9	+15	+11	− 3	− 9	− 7	+ 1
1 P.M.	− 9	− 5	− 4	− 8	−10	− 4	+ 3	+ 8	+ 2	− 9	−15	−16	− 6
2 ,,	−16	−13	− 8	−10	−11	− 6	− 6	− 2	−10	−13	−19	−21	−11
3 ,,	−17	−16	−11	−12	−13	− 8	−10	− 6	−13	−11	−15	−18	−12
4 ,,	−17	−16	−11	−12	−14	−11	−14	− 8	−13	− 7	−11	−15	−12
5 ,,	−13	−14	− 8	− 9	−12	−10	−15	− 8	−12	− 5	− 8	−11	−10
6 ,,	− 9	− 9	− 5	− 3	− 6	− 7	−16	−10	−11	− 2	− 4	− 7	− 8
7 ,,	− 2	− 2	+ 2	+ 5	+ 1	− 2	− 3	+ 2	+ 4	+ 4	+ 3	+ 1	+ 1
8 ,,	+ 3	+ 3	+ 9	+12	+ 8	+ 3	+ 2	+ 6	+ 9	+10	+ 9	+ 6	+ 6
9 ,,	+10	+ 8	+14	+18	+18	+13	+13	+13	+15	+14	+15	+12	+14
10 ,,	+13	+13	+17	+22	+21	+17	+12	+ 8	+10	+15	+20	+17	+16
11 ,,	+15	+15	+21	+27	+27	+21	+14	+ 9	+13	+18	+23	+19	+18
Midnight	+16	+16	+21	+28	+31	+22	+17	+11	+18	+21	+24	+20	+21

Experiments for Improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Professor CAREY FOSTER (*Chairman*), Lord KELVIN, Professors AYRTON, J. PERRY, W. G. ADAMS, *and* Lord RAYLEIGH, Drs. O. J. LODGE, JOHN HOPKINSON, *and* A. MUIRHEAD, Messrs. W. H. PREECE *and* HERBERT TAYLOR, Professor J. D. EVERETT, Professor A. SCHUSTER, Dr. J. A. FLEMING, Professors G. F. FITZGERALD, G. CHRYSTAL, *and* J. J. THOMSON, Messrs. R. T. GLAZEBROOK (*Secretary*), *and* W. N. SHAW, Rev. T. C. FITZPATRICK, Dr. J. T. BOTTOMLEY, Professor J. VIRIAMU JONES, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, *and* Mr. G. FORBES.

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THE work of testing resistance coils at the Cavendish Laboratory has been continued. A table of the coils tested is given.

TABLE I.

Ohms.

No. of Coil		Value of Coil	Temperature
Nalder, 3876 . . .	Ⱡ No. 376	·99916	14°·0
Nalder, 4320 . . .	Ⱡ No. 381	·99922	14°·1
Nalder, 4322 . . .	Ⱡ No. 382	·99743	15°·6
White	Ⱡ No. 383	1·00095	15°·15
Nalder, 4087 . . .	Ⱡ No. 384	10·0079	17°·35
Paul	Ⱡ No. 385	·99993	13°·7
Paul	Ⱡ No. 386	10·0041	13°·7
Paul	Ⱡ No. 387	100 (1 – ·00059)	13°·7
Paul	Ⱡ No. 388	1000 (1 – ·00197)	14°·2
Nalder, 4274 . . .	Ⱡ No. 389	·100050	15°·2
Nalder, 4275 . . .	Ⱡ No. 390	·100053	15°·2

TABLE I.—*Ohms*—continued.

No. of Coil		Value of Coil	Temperature
Nalder, 4051	No. 391	·99988	13°·4
Nalder, 4338	No. 393	·99902	13°·6
Nalder, 4339	No. 394	·99916	13°·7
Nalder, 4302	No. 395	·99925	14°·8
Nalder, 4303	No. 396	·99933	14°·6
Nalder, 4304	No. 397	·99932	14°·6
Nalder, 4273	No. 398	·99908	13°·55
Nalder, 4555	No. 399	·99923	13°·9
Nalder, 4562	No. 400	·99938	13°·9
Nalder, 4556	No. 401	9·9929	13°·8
Nalder, 4559	No. 402	9·9924	13°·8
Nalder, 4563	No. 403	9·9935	13°·8
Nalder, 4557	No. 404	100 (1 – ·00097)	14°·1
Nalder, 4560	No. 405	100 (1 – ·00113)	14°·2
Nalder, 4564	No. 406	100 (1 – ·00093)	14°·1
Nalder, 4565	No 407	100 (1 – ·00003)	14°·2
Nalder, 4558	No. 408	1000 (1 – ·00126)	13°·9
Nalder, 4561	No. 409	1000 (1 – ·00092)	14°·0
Nalder, 4566	No. 410	1000 (1 – ·00007)	13°·9
Paul, 15	No. 411	·99950	14°·7
Paul, 27	No. 412	1·00016	16°·4
Paul, 13	No. 413	9·9973	14°·8
Paul, 19 . . .	No. 414	10·0038	14°·75
Paul, 30	No. 415	100 (1 – ·00091)	14°·75
Paul, 29 . . .	No. 416	1000 (1 – ·00094)	14°·1
Burstall	No. 417	1·00026	13°·4
Elliott, 307 . . .	No. 418	·99971	13°·4
Nalder, 4340 . . .	No .419	1·00009	16°·85
Paul, 20	No. 420	·99760	16°·4
Paul, 32	No. 421	9·9997	16°·5
B.A. Units.			
Elliott, 87	No. 81	1·00080	16°·7
Muirhead	No. 392	·99996	13°·7

The Committee regret that the insulation of some of the coils referred to in their last Report, which had been selected for the new standards of resistance, as defined by the resolutions adopted at Edinburgh, has proved defective. Traces of acid have been discovered in the paraffin with which the coils were filled. The two one-ohm standards of the Association,[1] as well as two of the one-ohm standards of the Board of Trade,[2] were found in January last to have so low an insulation resistance between the coil and the case as to be useless.

Thus the labour spent in the testing of these coils has been wasted; much of it will need to be done again. The insulation of some of the other standard ohm coils is not satisfactory. The single ohm standards have therefore been remade, and the others are being refilled with carefully selected paraffin. The original B.A. units have not, so far as comparisons between them can show, changed their values during the year, and one set of new ohm standards also has shown no sign of change.

The Committee print, as an appendix to the Report, the report of the proceedings at the International Congress at Chicago, presented to the Secretary of State at Washington by the American delegate to the Conference.

During the year Professor J. V. Jones has determined, by the aid of his Lorenz apparatus, the absolute resistance of certain wire coils of about ·1 ohm. These have been compared with the standards of the Association by the Secretary. An account of these experiments is contained in Appendices II. and III. The resistance standards of the Association have been compared with those of the Board of Trade by Mr. Rennie and the Secretary. Details of this comparison will be found in Appendix IV., while in Appendix V. is given, by Mr. E. O. Walker, an account of a comparison between five coils belonging to the Indian Government, which have been for twenty-four years in India, and Dr. Muirhead's standards. Mr. Fitzpatrick has continued his work on the specific resistance of copper, and has drawn up a table (see Appendix VI.) reducing to the same units experimental results recently obtained by various observers. Appendix VII. contains the Final Report of the Electrical Standards Committee of the Board of Trade and the Order in Council relating to Standards for Electrical Measurement.

In consequence of the difficulty met with in the insulation of some of the coils, it was thought well to defer the purchase of other coils for which the grant of 25*l*. was obtained last year. The Committee are of opinion that it is desirable to complete their set of standards by obtaining from Germany certified copies of the standards of the Reichsanstalt. They recommend, therefore, that they be reappointed, with the addition of the name of Mr. Rennie, and with a grant of 25*l*.; that Professor G. Carey Foster be Chairman and Mr. R. T. Glazebrook Secretary.

APPENDIX I.

Report of the Action of the International Electrical Congress held in Chicago, August 1893, in the Matter of Units of Electrical Measure.

WASHINGTON, D.C.: *November* 6, 1893.

THE HON. W. Q. GRESHAM, *Secretary of State, Washington, D.C.*

SIR,—The undersigned, having been designated by you on May 12, 1893, as delegates to represent the United States in the International

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[1] *Report*, 1893, p. 129.

[2] *Ibid.*, 1892, p. 134.

Electrical Congress to be held in August at Chicago, beg to submit herewith a brief report showing the definitive action of said Congress in the matter of defining and naming units of electrical measure. The consideration of this important subject was left to what was known as the 'Chamber of Delegates' of the Congress, consisting only of those who had been officially commissioned by their respective Governments to act as members of said Chamber. After conference and correspondence with the leading electricians of Europe, it had been agreed that the maximum number of such delegates to be allowed to one nation should be five, and this number was allotted to the United States, Great Britain, Germany, and France. Other nations were allowed three or two, and in some instances one.

Delegates present and taking part in the discussions and action of the Chamber were as follows :—

Representing the United States.

Professor H. A. Rowland, Johns Hopkins University, Baltimore, Md.

Dr. T. C. Mendenhall, Superintendent of U.S. Coast and Geodetic Survey, and of Standard Weights and Measures, Washington, D.C.

Professor H. S. Carhart, University of Michigan, Ann Arbor, Mich.

Professor Elihu Thomson, Lynn, Mass.

Dr. E. L. Nichols, Cornell University, Ithaca, N.Y.

Representing Great Britain.

W. H. Preece, F.R.S., Engineer-in-Chief and Electrician, Post Office, England ; President of the Institution of Electrical Engineers, London.

W. E. Ayrton, City and Guilds of London Central Institution, Exhibition Road, London.

Professor Silvanus P. Thompson, D.Sc., F.R.S., Principal of the City and Guilds Technical College, Finsbury, London.

Alex. Siemens, 12 Queen Anne's Gate, Westminster, London, S.W.

Representing France.

E. Mascart, Membre de l'Institut, 176 Rue de l'Université, Paris.

T. Violle, Professeur au Conservatoire des Arts et Métiers, 89 Boulevard St. Michel, Paris.

De la Touanne, Telegraph Engineer of the French Government, 13 Rue Soufflot, Paris.

Edouard Hospitalier, Professeur à l'École de Physique et de Chimie industrielle de la Ville de Paris ; Vice-Président de la Société internationale des Electriciens, 6 Rue de Clichy, Paris.

Dr. S. Leduc, 5 Quai Fosse, Nantes.

Representing Italy.

Comm. Galileo Ferraris, Professor of Technical Physics and Electrotechnics in the R. Museo Industriale, Turin, Via Venti Settembre 46.

Representing Germany.

H.E. Hermann von Helmholtz, Präsident der physikalisch-technischen Reichsanstalt, Professor a. d. Universität, Berlin, Charlottenburg bei Berlin.

Dr. Emil Budde, Berlin N.W. Klopstockstrasse 53.

A. Schräder, Regierungsrath, Mitglied des kaiserl. Patentamts, Berlin.

Dr. Ernst Voit, Professor an der technischen Hochschule, München, Schwanthalerstrasse 73–3.

Dr. Otto Lummer, Mitglied der physikalisch-technischen Reichsanstalt, Charlottenburg, Berlin.

Representing Mexico.

Augustin W. Chavez, city of Mexico.

Representing Austria.

Dr. Johann Sahulka, Technische Hochschule, Wien.

Representing Switzerland.

A. Palaz, Professeur, Lausanne.
René Thury, Ingénieur, Florissant, Genève.

Representing Sweden.

M. Wennman, Byråchef i Rougle Telegrafstyrelsen, Stockholm.

Representing British North America.

Ormond Higman, Electrician, Standards Branch, Inland Revenue Department, Ottawa.

His Excellency Dr. H. von Helmholtz was made Honorary President of the Congress; Dr. Elisha Gray, of Chicago, was Chairman of the General Congress; and Professor H. A. Rowland, of Baltimore, was President of the Chamber of Delegates.

Meetings of the Chamber continued during six days, at the end of which its members unanimously agreed in the adoption of the following resolution:—

Resolved, That the several Governments represented by the delegates of this International Congress of Electricians be, and they are hereby, recommended to formally adopt as legal units of electrical measure the following: As a unit of resistance, the *international ohm*, which is based upon the ohm equal to 10^9 units of resistance of the C.G.S. system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass, of a constant cross-sectional area and of the length of 106·3 cm.

As a unit of current, the *international ampere*, which is one-tenth of the unit of current of the C.G.S. system of electro-magnetic units, and which is represented sufficiently well for practical use by the unvarying current which, when passed through a solution of nitrate of silver in water, and, in accordance with accompanying specifications,[1] deposits silver at the rate of 0·001118 of a gramme per second.

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[1] In the following specification the term silver voltameter means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time average of the current, or, if the current has been kept constant, the current itself, can be deduced.

In employing the silver voltameter to measure currents of about one ampere the following arrangements should be adopted:—

The kathode on which the silver is to be deposited should take the form of a

As a unit of electro-motive force, the *international volt*, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of one international ampere, and which is represented sufficiently well for practical use by $\frac{1000}{1434}$ of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of 15° C., and prepared in the manner described in the accompanying specification.[1]

As a unit of quantity, the *international coulomb*, which is the quantity of electricity transferred by a current of one international ampere in one second.

As a unit of capacity, the *international farad*, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

As a unit of work, the *joule*, which is equal to 10^7 units of work in the C.G.S. system, and which is represented sufficiently well for practical use by the energy expended in one second by an international ampere in an international ohm.

As a unit of power, the *watt*, which is equal to 10^7 units of power in the C.G.S. system, and which is represented sufficiently well for practical use by the work done at the rate of one joule per second.

As the unit of induction, the *henry*, which is the induction in a circuit when the electro-motive force induced in this circuit is one international volt, while the inducing current varies at the rate of one ampere per second.

The Chamber also voted that it was not wise to adopt or recommend a standard of light at the present time.

A more complete report of the operations of the Chamber will shortly be forwarded. This brief *résumé* of its definite action in reference to the matter of units is now submitted to facilitate the prompt dissemination among representatives of foreign Governments of the important results of a congress of whose success and fruitfulness the United States may justly be proud.

H. A. ROWLAND. ELIHU THOMSON.
T. C. MENDENHALL. E. L. NICHOLS.
H. S. CARHART.

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platinum bowl not less than 10 centimetres in diameter and from 4 to 5 centimetres in depth.

The anode should be a plate of pure silver some 30 sq. cm. in area and 2 or 3 mm. in thickness.

This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the anode from falling on to the kathode, the anode should be wrapped round with pure filter paper, secured at the back with sealing-wax.

The liquid should consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

[1] A committee, consisting of Messrs. Helmholtz, Ayrton, and Carhart, was appointed to prepare specifications for the Clark's cell. Their report has not yet been received.

APPENDIX II.

On a Determination of the International Ohm in Absolute Measure. By Professor J. V. Jones, *F.R.S., Principal of the University College of South Wales and Monmouthshire, Cardiff.*

The apparatus for the absolute measurement of electrical resistance in my laboratory at Cardiff was completed in 1890, and I first used it for the determination of the specific resistance of mercury in absolute measure.[1] This determination was made by direct measurement on a mercury column contained in a trough of paraffin wax. The results of five complete sets of observations were as follows:—

94103
94074
94093
94045
94021

The mean of these is 94067; and the extreme variation from the mean is 46, or about four parts in 10,000.

I suspected that much of the variation was due to the paraffin trough, the temperature of which varied slightly (about half a degree) during the observations, and was not accurately measurable owing to the low conductivity of the material. With variation of temperature there was variation of breadth, and the breadth of the trough entered as a primary factor into the calculation of the specific resistance.

When I proceeded to use the apparatus for the measurement of low-resistance standards of solid metal this was conclusively shown to be the case. I brought a set of measurements made on such a standard under the attention of the Section last year at Nottingham, in which the extreme variation from the mean was only about one part in 12,000.

This may be taken to be the normal performance of the apparatus; and seeing that it is an instrument of such precision, it seemed to me of interest to determine by the use of solid metal standards the relation between its indications and the results obtained by other observers for the value of the ohm.

With this end in view I obtained four coils from Messrs. Nalder Brothers—two platinum-silver ten-ohm coils and two manganine tenth-ohm coils. Mr. Glazebrook has measured them in terms of the international ohm; and I am much indebted to him for the pains he has been kind enough to take in making the determination. The following table gives their resistances and temperature coefficients:—

Coil Number	Resistance in International Ohm (Glazebrook)	Temperature Coefficients (Nalder)
3873	9·9919 at 14°·8 C.	·000300
3874	9·9926 at 14°·9 C.	·000276
4274	·100050 at 15°·2 C.	·000013
4275	·100053 at 15°·2 C.	·000013

These coils were arranged in manner similar to that adopted by Lord

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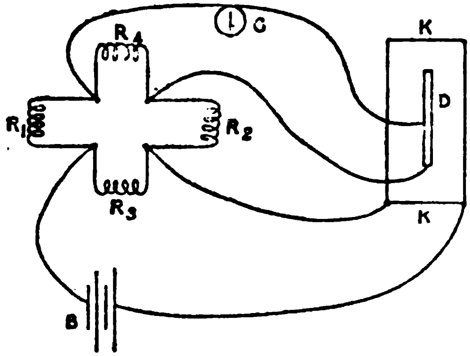
[1] *Phil. Trans.*, 1891, A.

Rayleigh in his determination of the ohm by the method of Lorenz (see fig. 1).

If there is no current through the galvanometer, there is equality between the E.M.F. due to the rotation of the disc in the field of the standard coil and the E.M.F. due to the current through R_4; and we have, if R_1, R_2, R_3, R_4 are the values of the four resistance coils in international ohms, and if x is the value of the international ohm in absolute measure,

FIG. 1.



R_1, R_2, 10-ohm coils.
R_3, R_4, ·1-ohm coils.
B, Battery.
G, Galvanometer.
D, Rotating disc.
K K, Standard coil.

$$\frac{R_2 R_4 x}{R_1 + R_2 + R_3 + R_4} = Mn,$$

where M = the coefficient of mutual induction of the standard coil and the circumference of the disc, and n = the rate of rotation of the disc.

The resistance coils are of B.A. pattern. They were immersed in water, and the temperatures of thermometers within the coil frames were read before and after each observation. A wooden box surrounded the four cans containing the coils.

The method of making the observations was the same as that described in the paper I read before the Section last year (*vide* Electrical Standards Committee Report, 1893).

The results are as follows, the figure in each case giving the value of the international ohm in true ohms.

July 7.—Standard coil carefully adjusted. Three-minute tapes.

	·999703
	·999761
	·999807
Mean .	·999757

July 9.—No readjustment of standard coil. One-minute tapes.

	·999757
	·999711
	·999683
	·999782
Mean	·999733

July 10, Morning.—Standard coil readjusted. One-minute tapes

·999734
·999818
·999726

Mean . ·999759

July 10, Afternoon.—No readjustment of standard coil. Three-minute tapes.

·999708
·999742
·999764

Mean . ·999738

July 11, Afternoon.—Standard coil readjusted. Three-minute tapes.

·999693
·999692
·999679

Mean . ·999688

July 12, Morning.—No readjustment of standard coil. Resistance coils reversed.

·999713
·999711
·999692

Mean . ·999705

July 12, Afternoon.—Standard coil readjusted. Resistance coils removed from the mercury cups and replaced. Three-minute tapes.

·999774
·999787
·999759

Mean . ·999773

July 13.—Standard coil readjusted. Resistance coils removed from mercury cups and replaced. Three-minute tapes.

·999847
·999809
·999782
·999842 (morning of the 14th)

Mean . ·999820

July 14, Morning.—Standard coil readjusted. Resistance coils removed and replaced. Three-minute tapes.

·999695
·999692
·999717

Mean . ·999701

July 14, Afternoon.—Standard coil readjusted. Resistance coils removed and replaced. Three-minute tapes.

·999853
·999866
·999875

Mean . ·999865

It is clear that in the above series the chief variations are due to changes consequent on readjustment of the standard coil, and the removal and replacement of the resistance coils in their mercury cups. Counting as independent only those of the observations before which there was readjustment of the standard coil or removal of the resistance coils from the mercury cups, the general mean is

·99976.

The maximum variation from the mean is ·000106, or about one part in 10,000.

Assuming that the international ohm is the resistance of a column of mercury at 0° of 1 sq. mm. sectional area, and 106·30 cm. long, we have as a result of the above measurement that the true ohm is the resistance of a column of mercury of the same sectional area and 106·326 cm. long.

The figure I arrived at in 1890, working direct on mercury, was 106·307, with a probable error of ±·011. The new result is therefore a little larger than I was prepared for. The accuracy of the result depends primarily on—

(i) The accuracy with which the resistance coils are known in terms of the international ohm.

(ii) The accuracy with which their temperatures are known at the times of observation.

(iii) The accuracy with which the coefficient of mutual induction of the coil and disc has been determined.

Upon the first point I can say little. Mr. Glazebrook knows better than anyone to what figure the values of the resistances may be relied on.

The effect of error in estimation of the temperatures of the coils can be but slight. The observations have been made in two ways, viz., with one-minute tapes, the current being put on only during the time of observation, and with three-minute tapes, the current being kept on continuously, whether observations were being made or not. During the last few days of the observations the current was kept passing through the coils night and day. I have calculated the effect that would be produced on the result obtained with one-minute tapes if all the heat generated by the current were to remain in the coils—an extreme case, obviously less favourable than the actual conditions. It is something less than two parts in 100,000. The smallness of the effect is due to the fact that if γ is the main current, a current equal to $\frac{200}{201}\gamma$ passes through the tenth-ohm manganine coil with its small temperature coefficient, and only $\frac{1}{201}\gamma$ through the platinum-silver coils; while the effect of underestimating the temperature of the manganine tenth-ohm coil is to produce an error in the result opposite in sign to that produced by underestimating the temperature of the platinum-silver coils.

There cannot, then, in the case of the one-minute tape observations be an appreciable error due to underestimation of the temperature. But the first four sets of observations show that the results of the one-minute tape observations and the three-minute tape observations are practically the same. Hence it follows that to the degree of accuracy aimed at our results are unaffected by error due to underestimation of the temperature.

It remains to consider the accuracy with which the coefficient of mutual induction of the coil and disc is known.

To calculate this coefficient we must know the radius of the disc and the mean radius of the coil. The circumference of the disc is a sufficiently true circle, the disc having been ground true in place. The measurement of its diameter presented no difficulty. It was determined on my Whitworth measuring machine to the ten-thousandth of an inch.

The mean radius of the coil cannot be determined with the same accuracy; but I believe that it is known to the thousandth of an inch. The coil consists of a single layer of silk-covered wire wound in a screw thread cut on a brass frame. It was measured along eighteen diameters in the Whitworth machine with the following results:—

Diameter	Measurement	Diameter	Measurement
0°–180°	21·0898	90°–270°	21·1038
10–190	21·0929	100–280	21·1056
20–200	21·0951	110–290	21·1041
30–210	21·0933	120–300	21·1014
40–220	21·0960	130–310	21·0979
50–230	21·0998	140–320	21·0945
60–240	21·1017	150–330	21·0924
70–250	21·1026	160–340	21·0900
80–260	21·1044	170–350	21·0910
	Max., 21·1056		
	Min., 21·0898		Mean, 21·09757
	·0158		$t=17°$ C.

These measures clearly show that the coil is elliptical in section, the difference between the major and minor axes being about ·008 inch, or about one part in 1,300.

In considering the possible effect of this ellipticity on the result, it must be borne in mind that the formula $R=Mn$ implies that the coil is circular. The true formula is

$$R=2\pi n\int_{a_0}^{a_1} aH\,da$$

where a_0 and a_1 are the distances from the centre of the disc at which the internal and external brushes are applied, and H is the magnetic force at a distance a from the centre when unit current is passing through the coil.

This is an unpleasant integral for an elliptical coil, and it has not yet yielded to persuasion. It is, however, satisfactory to note that as in my apparatus the brush radius makes but a small angle with the minor axis (about 15°), I am, in so far as the ellipticity of the coil affects matters at all, underestimating the integral, and hence underestimating the international ohm. Any correction for ellipticity hereafter calculated will make the value of the international ohm deduced from my observations nearer to and not further from the true ohm.

It is further to be noticed that the formula $R=Mn$ applies only if there is exact coincidence of the axes of the disc and coil. It has been customary to consider the adjustment for centre as of secondary importance in Lorenz's method. It would be so if the formula $R=Mn$ were applicable when the centres of coil and disc do not coincide, for a slight displacement only affects the coefficient of mutual induction to a secondary degree. But we are not concerned with the coefficient of mutual induction in this case. We are concerned with another integral, viz.,

$$2\pi\int_{a_0}^{a_1} a\mathrm{H}da$$

and the adjustment for centre is in truth of primary importance. Special attention should therefore be paid to this in designing apparatus for the absolute measurement of resistance by this method.

One other point remains to be noticed in this connection, viz., the possible effect of the difference of the temperature of the coil and disc when measured and when in use. On calculating the correction to be applied for this cause I find it negligible.

Again, I would say, as I said last year, that the chief value of these observations consists in the proof they afford of the precision with which the absolute measurement of resistance may be made by this method. A well-constructed apparatus of the kind in a national laboratory—say the Laboratory of the Board of Trade—will, I believe, prove to be the best ultimate standard of electrical resistance.

APPENDIX III.

Comparison of the Standard Coils used by Professor Jones with the Standards of the Association. By R. T. GLAZEBROOK.

The tenth-ohm standards of manganin wire whose value in absolute measure was determined by Professor Jones by means of the experiments described in Appendix II. were compared with the standards of the Association in the following manner. A Wheatstone's bridge was formed in which the arms were the tenth-ohm to be tested, two single-ohm coils and a ten-ohm coil; if the coils had these values exactly, there would of course always have been a balance; since, however, the coils were not accurately correct, there was usually a small current through the galvanometer; the balance, however, could be obtained by placing a large resistance as a shunt either to one of the one-ohm coils or to the ten-ohm coil: this resistance, which varied from 10,000 to 20,000 ohms, was taken from a good box of coils. The resistance of the ten-ohm and of the two one-ohm coils being known, that of the tenth-ohm coil could readily be found.

The four coils dipped into four mercury cups cut in an ebonite block; the bottoms of these cups were copper pieces some 3 to 4 mm. thick.

Binding screws screwed into these copper pieces and rising above the mercury served to connect the bridge to the galvanometer and the battery.

The mercury cups were somewhat large—about 2·5 cm. in diameter—and it was found on January 16 that distinct differences could be observed by moving the tenth-ohm coils slightly so as to bring their terminals either close to or as far as possible from the feet of the one-ohm coils which dipped into the same cups. After this date then two sets of measurements were made for each coil at each observation: in the one the terminals of the coils in any cup were put as close together as possible, in the other the terminals of the tenth-ohm coils were placed at some distance from those of the other coil in the same cup.

Both sets of values are given in the table as a means of showing the delicacy of the observations and the error arising from this cause. The tenth-ohm coils were weighted so as to press firmly on to the copper bottoms. No variation was produced by shifting the ten-ohm coil in its cup.

One or two Leclanché cells were used in the various experiments : the coils were in water-baths and the temperatures read by a standardised Kew thermometer.

The standard coils used were—

Elliott 264 = 1 + ·000312 (t − 15·45).
Nalder 3715 = 1 + ·000260 (t − 14·95).
Elliott 289 = 10 + ·002600 (t − 15·40).

The results of the experiments are given in the following table.

In the results of the experiments made after January 15 the two values given correspond to the two positions of the coil in the mercury cup. They are included to show the magnitude of the error, which may be due to the resistance of the copper bottoms of the cup.

Tables giving Values of Nalder No. 4274 𝔅𝔄 *No.* 389 *in terms of the Ohm Standards of the Association.*

Date	Temperature	Value of resistance	
December 29, 1893 . .	14·4°	·100052	
January 13, 1894 . .	15·2	·100051	
„ 15, „ . .	14·8	·100056	
„ 16, „ . .	15·5	·100051	·100056
„ 17, „ . .	16·4	·100049	·100058
„ 27, „ . .	16·9	·100057	·100066
February 20, „ . .	14·1	·100036	·100041
March 17, „ . .	14·1	·100045	·100046
Mean . . .	15·2	·100050	·100054

Values of Nalder 4275 𝔅𝔄 390.

Date	Temperature	Value of resistance	
December 29, 1893 . .	14·6°	·100059	
January 13, 1894 . .	15	·100053	
„ 15, „ . .	15	·100058	
„ 16, „ . .	15·8	·100055	·100061
„ 17, „ . .	16·4	·100051	·100059
„ 27, „ . .	16 6	·100058	·100065
February 20, „ . .	14·1	·100043	·100047
March 17, „ . .	13·8	·100051	·100051
Mean . . .	15·2	·100053	·100057

Thus, the values of the coils at 15°·2 are respectively for

𝔅𝔄 389 . . ·100050 ohm,

and for

𝔅𝔄 390 . . ·100053 ohm,

while in each case the resistance introduced by placing the contact pieces of the tenth-ohm coils at some distance from those of the other coils is ·000004 ohm

APPENDIX IV.

Comparison of certain Ohm-Standards of the Board of Trade.

By J. RENNIE.

In the accompanying table are given the results of comparisons which were made on May 29 and 30, 1894, at the Cavendish Laboratory, between the three unit coils :—

Elliott's No. 261,
Elliott's No. 263,
Nalder's No. 3876,

belonging to the Electrical Department of the Board of Trade, and the B.A. standards, Flat, F, G, and H.

The bridge was of the Carey Foster pattern, constructed for the Department by Nalder Bros. and Co., and the slide wire used was the one marked B, having a value of ·000,050,9 ohm per division.

A 100-ohm coil, Elliott's No. 291, was placed in parallel with the Board of Trade coil for each comparison, this being effected by a large mercury-in-paraffin bath.

Temperatures were measured by a mercury-in-glass thermometer, which had been standardised at Kew.

B.A. Coil	Temp. of B.A. Coil	Temp. of B. of T. Coil	Observed Value	Chart * alueV	Difference, Chart observed
			No. 261 Coil.		
Flat .	12·54	12·58	·999156	·999142	−·000014
F . .	12·53	12·45	·999064	·999106	+·000042
G . .	12·90	12·97	·999217	·999262	+·000045
			No. 263 Coil.		
Flat .	12·50	12·53	·999136	·999140	+·000004
F . .	12·60	12·48	·999074	·999124	+·000050
G . .	12·80	12·98	·999217	·999271	+·000054
H . .	12·85	13·08	·999299	·999304	+·000005
			No. 3876 Coil.		
Flat .	12·60	12·45	·998808	·99879	−·000018
F . .	12·50	12·36	·998727	·99876	+·000049
G . .	12·70	12·23	·998697	·99874	+·000043
H . .	12·40	12·30	·998768	·99876	−·000008

* The chart referred to, for No. 261 and No. 263 coils, is one supplied for these coils by Mr. Glazebrook, and is dated March 1892. The chart referred to in the case of No. 3876 was constructed from comparisons made by Nalder Brothers between it and their 'master coil,' No. 3717. The coils Nos. 263 and 261 were compared on May 29, 1894, before beginning the above-mentioned series of comparisons. They were found exactly equal, when the temperatures were—No. 263, 12°·65 C.; No. 261, 12°·62 C. The chart values at these temperatures are—No. 263, 0·999175; No. 261, 0·999156; showing a difference of 19×10^{-6} ohms. The corresponding differences deduced from the above table are—from Flat, 18×10^{-6} ohms; from F, 8×10^{-6} ohms; from G, 9×10^{-6} ohms. The comparison No. 261—H is omitted, as the difference obtained was obviously much too large, and must have been caused by some undetected interference. It is evident from the eleven results given in the table that the difference between the coils Nos. 263 and 261 as deduced from comparison with H must be something like 10×10^{-6} ohms. [Note added October 5, 1894.]

APPENDIX V.

Table showing Values of five Standard Coils B.A. Units belonging to the Indian Government as compared with Dr. Muirhead's Standard at his Laboratory. By E. O. Walker, *C.I.E., M.I.E.E., Late Superintendent in the Government Telegraph Department in India.*

Standard used, No. 78, marked right at 15°·7 C., taken as correct. This standard, tested April 27, 1893, against a No. 68 Glazebrook, gave a ratio $\frac{\text{coil}}{\text{standard}}$ of 1·00015 at 16° C., and 1·00018 at 15°·4 C

Temperature of water, 20°·2 C.

Number	Marked right at	Difference	Correct at
106	15°·1 C.	+ ·023 per cent.	14°·0 C.
108	15°·3 C.	+ ·126 „	11°·7 C.
110	15°·3 C.	− ·028 „	16°·6 C.
111	15°·5 C.	+ ·055 „	13°·9 C.
114	15°·1 C.	+ ·004 „	15°·6 C.

Apparatus used, one metre bridge of platinum-iridium wire with a supplementary coil at each end of 20,012 millimetres. Suspended coil galvanometer, resistance 15 ohms (Muirhead and Co.'s). Trough, 45 × 7¼ × 5 inches; depth of water 2¾ inches; quantity of water, 6½ gallons; battery used, 1 Hellesen's Dry Cell, No. 3; E.M.F., 1·4 volt.

The interest attaching to these tests lies especially in the fact that the standard coils have been exposed to the climate of Calcutta for twenty-four years. They were made, I understand, by Dr. A. Muirhead when in Dr. Matthiessen's laboratory, under the supervision of the latter.

In reducing the observations from 20°·2 to the temperatures given, it has been assumed that all the coils have the same temperature coefficient.

APPENDIX VI.

On the Specific Resistance of Copper and of Silver.

By Rev. T. C. Fitzpatrick.

As lately several observers have published the results of measurements made on the specific resistance of copper, it may be worth while to collect these results together in tabular form.

The resistances of metals may be expressed in terms of equal weight or of equal volume; that is, as the resistance of a wire of the given material such that one metre of it weighs one gramme, or as the resistance between opposite faces of a cube of the material each face of which is one square centimetre. I have pointed out that Matthiessen[1] considered the first as the most satisfactory mode of expressing resistances, and for these results alone did he make all the actual experiments; the results for specific resistances were calculated from these with the help of specific gravity values obtained in many cases from tables, and not determined directly for the wires used.

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[1] *B.A. Report*, 1890, p. 129.

Only in cases where considerable masses of the material are used can the specific gravity, and from this the cross-section of the wires, be accurately determined. There is, therefore, an evident advantage in expressing results in terms of weight, as then the determination of the cross-section of the wires becomes unnecessary, and there is no reason why an accuracy of one in two or three thousand should not be attained.

Again, it is found that different samples of copper have different densities, according to the method by which they have been prepared; in a table[1] which I published on a previous occasion the variation is from 3·86 to 8·95. Mr. Swan[2] gives a value as high as 8·9587.

From samples of copper of the same quality I have had wires drawn which differed in density; it was always found that the denser the copper the less is its resistance, and the difference affects much more the results expressed as specific resistances than when expressed as the resistance for a gramme per metre.

This is another reason for expressing the results in these terms, at least as well as specific resistances, and for actual practical purposes it is a question of weight rather than volume.

In the following tables the results are given for a temperature of 18° C. in C.G.S. units:—

TABLE A.—*Hard-drawn Copper Wires.*

Resistance of wire such that the metre weighs one gramme	Specific resistance per cubic centimetre	Observer
1550×10^5	1743	Matthiessen[3]
	1720	Swan and Rhodin[4]
1550	1726	Fitzpatrick[5]
1527	1708	„ (copper supplied by Messrs. Bolton)

TABLE B.—*Annealed Wires.*

Resistance of wire such that the metre weighs one gramme	Specific resistance per cubic centimetre	Observer
1516×10^5	1704	Matthiessen[3]
	1681	Fleming and Dewar[6]
	1680	Swan and Rhodin[4]
1488	1665	Fitzpatrick[5] (copper supplied by Messrs. Bolton)
1488		(Wire sent by Mr. Swan)

From Table A it will be seen that Messrs. Swan and Rhodin obtained a value rather lower than that which I got for copper, prepared by myself, and which, expressed as the resistance of a wire one metre long weighing one gramme, is identical with the value that Matthiessen obtained; but the resistance of all these specimens is distinctly greater than that of the copper kindly sent me by Messrs. Bolton—which seems to bear out the statement, which I have previously made, that it is impossible to prepare wires on the small scale which are of the same quality, *i.e.*, probably due to density, as the best specimens specially prepared by large manufacturers.

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[1] *B.A. Report*, 1890, p. 125.

[2] *Nature*, vol. l. p. 165.

[3] *B.A. Report*, 1864.

[4] *Nature*, vol. l. p. 165.

[5] *B.A. Report*, 1890, p. 125

[6] *Phil. Mag*, vol. xxxvi. p. 287.

In Table B are given the results of measurements on three specimens of copper prepared by Mr. Swan: one was given to Profs. Dewar and Fleming; a second was examined by Mr. Swan himself, and a third specimen he kindly sent to me; the quality of the copper in the three cases may therefore be expected to be the same.

The results of Profs. Dewar and Fleming and Messrs. Swan and Rhodin are expressed only as specific resistances, whilst the result of my measurement is only given for a wire one metre long weighing one gramme. The weight of the copper wire, as measured, was only three grammes, and that does not allow the accurate determination of the specific gravity of the sample. The value I obtain for its resistance is identical with that for the sample of annealed copper wire sent me by Messrs. Bolton.

If it be considered to have the same specific gravity as that sample (8·94) its specific resistance in C.G.S. units is 1665; a value distinctly smaller than that obtained by Messrs. Swan and Rhodin, whose result is practically identical with that of Profs. Dewar and Fleming.

Not only may wires drawn from the same specimen of copper have different densities and different resistances, but the variation of that resistance with change of temperature may be also different.

In the following table are given the temperature coefficients of various specimens of copper:—

$$R_t = R_0\,(1 + at).$$

R_0	a	Observer
—	·00387	Matthiessen.[1]
1561	·00428	Dewar and Fleming.[2]
1603*	·00408	Swan and Rhodin.[3]
1563	·00417	—
1592*	·00405	Fitzpatrick.
—	·00406	Kennedy and Fessenden.[4]
—	·00364	Benoit.[5]

* Hard-drawn wires.

Influence of Annealing.—As is well known, annealed wires have a less resistance than hard-drawn wires, but the variation of resistance according as the wires are annealed or hard-drawn differs considerably for different materials. For silver it is as much as 10 per cent., whereas for copper it is less than 3 per cent.

I have made observations from time to time on the resistance value of specimens of hard-drawn copper wire, all pieces of the same coil, which were sent me in 1889 by Messrs. Bolton and Son. From the results of these measurements it will be seen that a hard-drawn wire seems to fall in resistance with lapse of time. The coil of wire has been left hanging in the laboratory, and has not been treated with any special care.

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[1] *B.A. Report*, 1864.

[2] *Phil. Mag.*, vol. xxxvi. p. 287.

[3] *Nature*, vol. l. p. 165.

[4] *Electricity*, vol. v. p. 165.

[5] *Comptes Rendus*, lxxvi. p. 345.

Date	Temperature	Resistance of wire 1 metre long weighing 1 gramme
July 1890	18°	1528×10^5
August 26, 1891 . . .	18°	1525
March 7, 1892 . . .	18°	1522
January 1894 . . .	18°	1520
July 1894	18°	1519

The fall in resistance is small, and for the period of nearly five years does not amount to more than ⅓ per cent.

I have, for the sake of comparison, made a measurement of the resistance of a specimen of annealed copper wire sent me by the same firm, and for this the resistance value is identical with that obtained at a previous date :—

Date	Temperature	Resistance of wire 1 metre long weighing 1 gramme
October 1889 . . .	18°	1488×10^5
July 1894	18°	1487·8

This, on the whole, is what one would expect. In the case of wires of other material the change would probably be greater, as the difference in resistance between annealed and hard-drawn copper wires is less than that for wires of other materials.

In my previous communication a method[1] of annealing was described which gave satisfactory results. The wire was packed in asbestos and fine carbon in a copper vessel and heated for twenty-four hours. The following results amongst others were obtained :—

Hard-drawn 18°	Annealed 18°	Difference
1527×10^5	1489	39
1526	1488	38

Matthiessen's values are :—

1550	1516	34

Messrs. Swan and Rhodin give for the values of the specific resistance :—

Hard-drawn 18°	Annealed 18°	Difference
1720	1680	40

I have recently been annealing copper wires by heating them in boiling paraffin (220°); and after slow cooling the wires seem to be completely annealed :—

Hard-drawn 18°	Annealed 18°	Difference
1526	1486	40

A wire sent me as annealed gave the result :—

Annealed 18°, 1488

This wire was then hardened, and, reannealed as above described, gave the value:—

Annealed 18°, 1489

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[1] *B.A. Report*, 1890, p. 126.

Either of these two methods seems to give satisfactory results. For completely annealing silver wires the temperature of the paraffin bath is not sufficiently high, but from the results of my measurements for silver, for which the influence of annealing is very considerable, it can be seen that the first method is quite satisfactory.

SILVER.

Many of the older measurements for resistances and conductivities are expressed in terms of the resistance of pure silver : this was the case with Matthiessen's earlier results.

Some measurements therefore made on silver wires are given, together with the results obtained by Matthiessen and Profs. Dewar and Fleming for the sake of comparison.

Several samples of silver wires were supplied by Messrs. Johnson and Matthey : one of these was stated to be absolutely pure.

The results are expressed for wires weighing one gramme per metre.

—	Hard-drawn	Annealed
Silver I.	1816×10^5	1739×10^5
„	1814	1741
„	1816	1721
Silver II.	1799	1722
Silver III., pure . . .	1777	1666
„ . . .	1773	1666
„ . . .	1767	—

The difference between the values for the hard-drawn wires is probably due to the fact that they had to be further drawn down after I had received them to enable me to measure them on my bridge.

Matthiessen's value	For wire 1 metre long weighing 1 gramme	Resistance per c.c.
Hard-drawn . . .	1779×10^5	1694[1]
Annealed	1639	1561

Profs. Dewar[2] and Fleming give as the value for an annealed pure silver wire 1468 C.G.S. at 0° C. with the temperature coefficient of ·004 ; the value at 18° is therefore for the specific resistance 1574.

For most of the wires which I measured the specific gravities were determined ; for the wires Silver I. there is practically no difference between the values obtained for the annealed and hard-drawn wires, the values varying from 10·496 to 10·511.

For the wires Silver III. the values varied from 10·49 to 10·50 ; using the mean value 10·495 I get for the specific resistances the following values :—

—	Hard-drawn wire	Annealed
Specific resistance in C.G.S. units at 18°	1689	1587

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[1] Using the value 10·5 as the specific gravity of silver.

[2] *Phil. Mag.*, vol. xxxvi.

In the case of copper[1] with increase of purity there is a decrease in the difference in resistance between annealed and hard-drawn wires. With silver the reverse is the case.

Silver	I.—Difference	75
„	II.—Difference	77
„	III.—Difference	107

The value that I obtained for the hard-drawn wire is very nearly the same as that given by Matthiessen, but he obtained a greater decrease in resistance on annealing. He states[2] that for different pieces of the same wire there was a variation of from 6 to 10 per cent.; so that the difference between his value and that which I have obtained for a sample of pure silver is not greater than might be expected.

The considerable variation in all the values given above makes it clear that the values of the specific resistance depend not simply on the purity of the material, but on a number of other factors, which will be different in the cases of different wires of the same material, and that therefore we cannot expect to attain to any great degree of accuracy in the determination of specific resistances as distinguished from the accurate measurement for some particular wire.

APPENDIX VII.

Final Report of the Electrical Standards Committee of the Board of Trade.

To the RIGHT HON. JAMES BRYCE, M.P.,
President of the Board of Trade.

Since the date of our last Report the Board of Trade have laid before us a *résumé* of the action of the International Electrical Congress held in Chicago in August 1893 to determine the units of electrical measurement. We were also informed by the Board of Trade that her Majesty's Government had been invited by the United States Ambassador in London to take steps to adopt the recommendations of the Congress.

These recommendations, so far as they refer to the units of electrical resistance, electrical current, and electrical pressure, are substantially the same as those suggested for adoption in our previous Reports.

We see no reason for further delay in the legalisation of standards of the above-mentioned units, and we have prepared and attach a revised Draft Order in Council,[3] which we advise may be submitted for her Majesty's gracious approval.

The accompanying notes[4] to the specification for the Clark's cell have been communicated by Mr. Glazebrook, and will be found of great assistance in the preparation of this form of cell.

(Signed) COURTENAY BOYLE. KELVIN.
FRANCIS J. S. HOPWOOD. P. CARDEW.
W. H. PREECE. RAYLEIGH.
G. CAREY FOSTER. R. T. GLAZEBROOK.
J. HOPKINSON. W. E. AYRTON.
T. W. P. BLOMEFIELD, *Secretary.*

August 2, 1894.

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[1] *B.A. Rep*, 1890, p. 126.

[2] *Phil. Trans.*, 1862, p. 7

[3] The Order in Council is printed in the form in which it has since received her Majesty's approval.

[4] For the notes see p. 141.

Order in Council regarding Standards for Electrical Measurements.

At the Court at Osborne House, Isle of Wight, August 23, 1894.
Present: The Queen's Most Excellent Majesty in Council.

Whereas by 'The Weights and Measures Act, 1889,' it is among other things enacted that the Board of Trade shall from time to time cause such new denominations of standards for the measurement of electricity as appear to them to be required for use in trade to be made and duly verified.

And whereas it has been made to appear to the Board of Trade that new denominations of standards are required for use in trade based upon the following units of electrical measurement, viz.—

1. The ohm, which has the value 10^9 in terms of the centimetre and the second of time, and is represented by the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass of a constant cross-sectional area and of a length of 106·3 centimetres.

2. The ampere, which has the value $\frac{1}{10}$ in terms of the centimetre, the gramme, and the second of time, and which is represented by the unvarying electric current which when passed through a solution of nitrate of silver in water in accordance with the specification appended hereto, and marked A, deposits silver at the rate of 0·001118 of a gramme per second.

3. The volt, which has the value 10^8 in terms of the centimetre, the gramme, and the second of time, being the electrical pressure that if steadily applied to a conductor whose resistance is one ohm will produce a current of one ampere, and which is represented by ·6974 ($\frac{1000}{1434}$) of the electrical pressure at a temperature of 15° C. between the poles of the voltaic cell known as Clark's cell set up in accordance with the specification appended hereto, and marked B.

And whereas they have caused the said new denominations of standards to be made and duly verified.

Now, therefore, her Majesty, by virtue of the power vested in her by the said Act, by and with the advice of her Privy Council, is pleased to approve the several denominations of standards set forth in the schedule hereto as new denominations of standards for electrical measurement.

C. L. Peel.

SCHEDULE.

I.—*Standard of Electrical Resistance.*

A standard of electrical resistance denominated one ohm being the resistance between the copper terminals of the instrument marked 'Board of Trade Ohm Standard Verified, 1894,' to the passage of an unvarying electrical current when the coil of insulated wire forming part of the aforesaid instrument and connected to the aforesaid terminals is in all parts at a temperature of 15°·4 C.

II. *Standard of Electrical Current.*

A standard of electrical current denominated one ampere being the current which is passing in and through the coils of wire forming part of the instrument marked 'Board of Trade Ampere Standard Verified, 1894,' when on reversing the current in the fixed coils the change in the forces acting upon the suspended coil in its sighted position is exactly balanced by the force exerted by gravity in Westminster upon the iridio-platinum weight marked A and forming part of the said instrument.

III.—*Standard of Electrical Pressure.*

A standard of electrical pressure denominated one volt, being one hundredth part of the pressure which when applied between the terminals forming part of the instrument marked 'Board of Trade Volt Standard Verified, 1894,' causes that rotation of the suspended portion of the instrument which is exactly measured by the coincidence of the sighting wire with the image of the fiducial mark A before and after application of the pressure and with that of the fiducial mark B during the application of the pressure, these images being produced by the suspended mirror and observed by means of the eyepiece.

In the use of the above standards the limits of accuracy attainable are as follows:—

For the ohm, within one hundredth part of one per cent.
For the ampere, within one tenth part of one per cent.
For the volt, within one tenth part of one per cent.

The coils and instruments referred to in this schedule are deposited at the Board of Trade Standardising Laboratory, 8 Richmond Terrace, Whitehall, London.

SPECIFICATIONS REFERRED TO IN THE FOREGOING ORDER IN COUNCIL.

SPECIFICATION A.

In the following specification the term silver voltameter means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time-average of the current, or if the current has been kept constant the current itself, can be deduced.

In employing the silver voltameter to measure currents of about 1 ampere the following arrangements should be adopted. The kathode on which the silver is to be deposited should take the form of a platinum bowl not less than 10 centimetres in diameter, and from 4 to 5 centimetres in depth.

The anode should be a plate of pure silver some 30 square centimetres in area and 2 or 3 millimetres in thickness.

This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the anode from falling on to the kathode, the anode should be wrapped round with pure filter paper, secured at the back with sealing-wax.

The liquid should consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of making a Measurement.

The platinum bowl is washed with nitric acid and distilled water, dried by heat, and then left to cool in a desiccator. When thoroughly dry it is weighed carefully.

It is nearly filled with the solution, and connected to the rest of the circuit by being placed on a clean copper support to which a binding screw is attached. This copper support must be insulated.

The anode is then immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are made.

Contact is made at the key, noting the time of contact. The current is allowed to pass for not less than half an hour, and the time at which contact is broken is observed. Care must be taken that the clock used is keeping correct time during this interval.

The solution is now removed from the bowl and the deposit is washed with distilled water and left to soak for at least six hours. It is then rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160° C. After cooling in a desiccator it is weighed again. The gain in weight gives the silver deposited.

To find the current in amperes, this weight, expressed in grammes, must be divided by the number of seconds during which the current has been passed, and by 0·001118.

The result will be the time-average of the current, if during the interval the current has varied.

In determining by this method the constant of an instrument the current should be kept as nearly constant as possible, and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated by the voltameter, corresponds to this reading.

SPECIFICATION B.

ON THE PREPARATION OF THE CLARK CELL.

Definition of the Cell.

The cell consists of zinc or an amalgam of zinc with mercury and of mercury in a neutral saturated solution of zinc sulphate and mercurous sulphate in water, prepared with mercurous sulphate in excess.

Preparation of the Materials.

1. *The Mercury.*—To secure purity it should be first treated with acid in the usual manner, and subsequently distilled *in vacuo.*

2. *The Zinc.*—Take a portion of a rod of pure redistilled zinc, solder to one end a piece of copper wire, clean the whole with glass paper or a steel burnisher, carefully removing any loose pieces of the zinc. Just before making up the cell dip the zinc into dilute sulphuric acid, wash with distilled water, and dry with a clean cloth or filter paper.

3. *The Mercurous Sulphate.*—Take mercurous sulphate, purchased as pure, mix with it a small quantity of pure mercury, and wash the whole

thoroughly with cold distilled water by agitation in a bottle; drain off the water, and repeat the process at least twice. After the last washing drain off as much of the water as possible.

4. *The Zinc Sulphate Solution.*—Prepare a *neutral* saturated solution of pure ('pure recrystallised') zinc sulphate by mixing in a flask distilled water with nearly twice its weight of crystals of pure zinc sulphate, and adding zinc oxide in the proportion of about 2 per cent. by weight of the zinc sulphate crystals to neutralise any free acid. The crystals should be dissolved with the aid of gentle heat, but the temperature to which the solution is raised should not exceed 30° C. Mercurous sulphate treated as described in 3 should be added in the proportion of about 12 per cent. by weight of the zinc sulphate crystals to neutralise any free zinc oxide remaining, and the solution filtered, while still warm, into a stock bottle. Crystals should form as it cools.

5. *The Mercurous Sulphate and Zinc Sulphate Paste.*—Mix the washed mercurous sulphate with the zinc sulphate solution, adding sufficient crystals of zinc sulphate from the stock bottle to ensure saturation, and a small quantity of pure mercury. Shake these up well together to form a paste of the consistence of cream. Heat the paste, but not above a temperature of 30° C. Keep the paste for an hour at this temperature, agitating it from time to time, then allow it to cool; continue to shake it occasionally while it is cooling. Crystals of zinc sulphate should then be distinctly visible, and should be distributed throughout the mass. If this is not the case add more crystals from the stock bottle, and repeat the whole process.

This method ensures the formation of a saturated solution of zinc and mercurous sulphates in water.

To set up the Cell.

The cell may conveniently be set up in a small test-tube of about 2 centimetres diameter and 4 or 5 centimetres deep. Place the mercury in the bottom of this tube, filling it to a depth of, say, ·5 centimetre. Cut a cork about ·5 centimetre thick to fit the tube; at one side of the cork bore a hole through which the zinc rod can pass tightly; at the other side bore another hole for the glass tube which covers the platinum wire; at the edge of the cork cut a nick through which the air can pass when the cork is pushed into the tube. Wash the cork thoroughly with warm water, and leave it to soak in water for some hours before use. Pass the zinc rod about 1 centimetre through the cork.

Contact is made with the mercury by means of a platinum wire about No. 22 gauge. This is protected from contact with the other materials of the cell by being sealed into a glass tube. The ends of the wire project from the ends of the tube; one end forms the terminal, the other end and a portion of the glass tube dip into the mercury.

Clean the glass tube and platinum wire carefully, then heat the exposed end of the platinum red-hot, and insert it in the mercury in the test-tube, taking care that the whole of the exposed platinum is covered.

Shake up the paste and introduce it without contact with the upper part of the walls of the test-tube, filling the tube above the mercury to a depth of rather more than 1 centimetre.

Then insert the cork and zinc rod, passing the glass tube through the hole prepared for it. Push the cork gently down until its lower surface is nearly in contact with the liquid. The air will thus be nearly all expelled, and the cell should be left in this condition for at least twenty-four hours before sealing, which should be done as follows.

Melt some marine glue until it is fluid enough to pour by its own weight, and pour it into the test-tube above the cork, using sufficient to cover completely the zinc and soldering. The glass tube containing the platinum wire should project some way above the top of the marine glue.

The cell may be sealed in a more permanent manner by coating the marine glue, when it is set, with a solution of sodium silicate, and leaving it to harden.

The cell thus set up may be mounted in any desirable manner. It is convenient to arrange the mounting so that the cell may be immersed in a water-bath up to the level of, say, the upper surface of the cork. Its temperature can then be determined more accurately than is possible when the cell is in air.

In using the cell sudden variations of temperature should as far as possible be avoided.

The form of the vessel containing the cell may be varied. In the H form the zinc is replaced by an amalgam of ten parts by weight of zinc to ninety of mercury. The other materials should be prepared as already described. Contact is made with the amalgam in one leg of the cell and with the mercury in the other by means of platinum wires sealed through the glass.

NOTES TO THE SPECIFICATION ON THE PREPARATION OF THE CLARK CELL.

The Mercurous Sulphate.—The treatment of the mercurous sulphate has for its object the removal of any mercuric sulphate which is often present as an impurity.

Mercuric sulphate decomposes in the presence of water into an acid and a basic sulphate. The latter is a yellow substance—turpeth mineral—practically insoluble in water; its presence at any rate in moderate quantities has no effect on the cell. If, however, it is formed, the acid sulphate is formed also. This is soluble in water, and the acid produced affects the electro-motive force. The object of the washings is to dissolve and remove this acid sulphate, and for this purpose the three washings described in the specification will in nearly all cases suffice. If, however, a great deal of the turpeth mineral is formed, it shows that there is a great deal of the acid sulphate present, and it will then be wiser to obtain a fresh sample of mercurous sulphate rather than to try by repeated washings to get rid of all the acid.

The free mercury helps in the process of removing the acid, for the acid mercuric sulphate attacks it, forming mercurous sulphate and acid which is washed away.

Pure mercurous sulphate when quite free from acid shows on repeated washing a faint primrose tinge, which is due to the formation of a basic mercurous salt, and is distinct from the turpeth mineral or basic mercuric sulphate. The appearance of this primrose tint may be taken as an indication of the fact that all the acid has been removed, and the washing may with advantage be continued until this primrose tint appears. Should large quantities of this basic mercurous salt be formed, the sulphate should be treated as described in the instructions for setting up Clark's cells issued from the Physical Technical Institute of Berlin, 'Zeitschrift für Instrumentenkunde,' 1893, Heft 5.

The Zinc Sulphate Solution.—The object to be attained is the preparation of a neutral solution of pure zinc sulphate saturated with $ZnSO_4 7H_2O$.

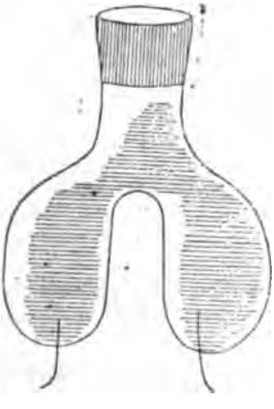
At temperatures above 30° C. the zinc sulphate may crystallise out in another form; to avoid this, 30° C. should be the upper limit of temperature. At this temperature water will dissolve about 1·9 time its weight of the crystals. If any of the crystals put in remain undissolved they will be removed by the filtration.

The zinc sulphate should be free from iron, and should be tested before use with sulphocyanide of potassium to ascertain that this condition is satisfied. If an appreciable amount of iron is present it should be removed by the method given in the directions already quoted, 'Zeitschrift für Instrumentenkunde,' 1893, Heft 5.

The amount of zinc oxide required depends on the acidity of the solution, but 2 per cent. will, in all cases which will arise in practice with reasonably good zinc sulphate, be ample. Another rule would be to add the zinc oxide gradually until the solution became slightly milky. The solution when put into the cell should not contain any free zinc oxide; if it does, then, when mixed with the mercurous sulphate, zinc sulphate and mercurous oxide are formed; the latter may be deposited on the zinc and affect the electro-motive force of the cell. The difficulty is avoided by adding as described about 12 per cent. of mercurous sulphate before filtration: this is more than sufficient to combine with the whole of the zinc oxide originally put in, if it all remains free. The mercurous oxide formed, together with any undissolved mercurous sulphate, is removed by the filtration.

The Mercurous Sulphate and Zinc Sulphate Paste.—Although, after the last washing of the mercurous sulphate, as much water as possible may have been drained off, sufficient water generally remains to necessitate the addition of a *very considerable* quantity of crystals of zinc sulphate from the stock bottle, in order to insure saturation, when the washed mercurous sulphate is added to the zinc sulphate solution as described in No. 4 of Specification B appended to the Order in Council.

FIG. 2.



If the sides of the test tube above the cork be soiled by the introduction of the paste, the marine glue doos not adhere to the glass; the liquid in the cell rises by capillary action between the glue and the glass, and may damage the cell.

The form of the vessel containing the cell may be varied. In the H form devised by Lord Rayleigh and modified by Dr. Kahle the zinc is replaced by an amalgam of zinc and mercury. The other materials should be prepared as already described. Contact is made with the amalgam in one leg of the cell and with the mercury in the other by means of platinum wires sealed through the glass.

The amalgam consists of about ninety parts of pure mercury mixed with ten parts of pure redistilled zinc. These are heated in a porcelain crucible to about 100° C., and gently stirred until the zinc is completely dissolved in the mercury. The amalgam is liquid while warm, and must be poured into the cell before it becomes solid on cooling.

The vessel containing the element consists of two vertical tubes. These, as shown in the figure, are closed below and open above into a common neck, which can be closed by a ground stopper of glass. The two tubes should be 2 cm. in diameter and 3 cm. in length. The neck should be at least 1·5 cm. in diameter and 2 cm. long. A short length of platinum wire is sealed through the bottom of each tube.

The end of the wire in one tube is covered by a small quantity of pure mercury, that in the other tube by the zinc-mercury amalgam.

Above the mercury a layer about 1 cm. thick of the mercurous sulphate paste is placed; above this, and also above the amalgam, a layer, also about 1 cm. in thickness, of zinc-sulphate crystals, and the vessel is filled up with the saturated zinc sulphate solution.

The zinc-sulphate crystals are obtained by evaporating at a temperature of less than 30° C. some of the zinc-sulphate solution prepared as in 4 of the specification.

The stopper is then inserted, leaving a small air bubble above the liquid, and sealed on the outside with shellac dissolved in alcohol.

The ends of the platinum wires outside the cell form the two poles, and should be connected to suitable terminals.

The Application of Photography to the Elucidation of Meteorological Phenomena.—Fourth Report of the Committee, consisting of Mr. G. J. SYMONS *(Chairman)*, Professor R. MELDOLA, Mr. J. HOPKINSON, *and* Mr. A. W. CLAYDEN *(Secretary)*. *(Drawn up by the Secretary.)*

IN presenting their report on the work of the last year your Committee have but little to say on the subject of the representation of clouds and lightning by photography. They consider that their collection is nearly complete so far as the different varieties of cloud form are concerned, and it is only likely to be increased slowly and at long intervals by photographs of scarce forms of clouds or by particularly interesting series. During the year the Secretary has secured many new negatives; but since the collection already includes satisfactory examples of the same types, it has not been thought desirable to add more duplicates, and the offers of co-operation from other photographers have not been fulfilled. With regard to photographs of lightning also the collection has not been increased, for your Committee have not been made aware of any such photographs which show any features not already familiar, and no opportunity has occurred for the Secretary to make any observations for the further elucidation of the known phenomena.

Your Committee propose to invite the Royal Meteorological Society to take charge of such photographs from their collection as are not likely to be required for further investigation.

The attention of the Committee has been drawn to another application of photography which seems to open up a possibility of very valuable work; this is in the measurement of cloud altitudes. This is a question which has become more important since the acceptance by the Munich

Congress of the system of cloud nomenclature devised by Hildebrandsson and Abercromby, and it is remarkable that so few actual measurements have been carried out.

So far as your Committee are aware, the only measurements of the kind which have been systematically organised, at least in this country, are those which were begun some years ago at Kew.

Now it is not only important to have more observations, but it is especially desirable to have them from other places than the vicinity of London for comparison, and in the residence of the Secretary at Exeter such an opportunity is presented.

In the course of experiments on methods of cloud photography it has been found easy to secure well-defined images of clouds even when the sun is in the middle of the field of view. If, then, two such photographs are taken simultaneously by a pair of cameras at some distance apart, there will be a displacement of the image relatively to that of the sun. The amount of this displacement will depend upon a number of things, but it will be increased by adding to the focal length of the lens and by increasing the distance between the two cameras. By knowing these values and the altitude and azimuth of the sun, the distance of the cloud and its height above the ground may be calculated without difficulty.

The azimuth and altitude of the sun at the time of exposure may be ascertained by direct observation, or it may be found by calculation from the known time at which exposure was made. There seems to be a manifest advantage in thus using the sun as a fixed point of reference, since it provides a means whereby any error in the observation of altitude and azimuth may be effectively checked.

Your Committee have therefore prepared a pair of cameras so constructed that they may be easily directed towards the sun. They are provided with lenses of 18 inches focus covering a plate of whole plate size, thereby giving a large displacement and allowing room for a displacement of several inches. The lenses are provided with adjustable shutters, which can be simultaneously freed by an electrical attachment. They are placed on stands, which serve as cupboards for them when not in use.

At present for purely trial purposes they are placed in the Secretary's garden at a distance of 35 yards, yet even that short distance gives a displacement of half an inch with clouds 3,780 feet distant. This, of course, is too small for very accurate measurement, and would be far smaller with high-level clouds, the determination of the altitudes of which is most important.

The intention of your Committee is to place them on a plot of level ground by the side of the London and South-Western Railway near Exeter. There is available a strip of waste ground, just over a quarter of a mile in length, commanding an uninterrupted view of the sun from sunrise until nearly sunset. The ground is level, and the cameras can be placed due east and west, thereby greatly simplifying the reduction of the observations. The directors of the London and South-Western Railway have kindly consented to allow the ground to be used under conditions which seem to your Committee quite satisfactory, but which involve the payment of a nominal rent of 1*l.* per annum; and the cameras would have been placed in position by the present time had it not been necessary to get another meeting of the Committee to sanction the agreement. The method is easy to apply, and promises to yield results at least as accurate as any which have yet been tried; so your Committee ask for reappointment, with a grant of 10*l.*

Earth Tremors.—Report of the Committee, consisting of Mr. G. J. Symons, Mr. C. Davison (*Secretary*), Sir F. J. Bramwell, Professor G. H. Darwin, Professor J. A. Ewing, Dr. Isaac Roberts, Mr. Thomas Gray, Sir John Evans, Professors J. Prestwich, E. Hull, G. A. Lebour, R. Meldola, *and* J. W. Judd, Mr. M. Walton Brown, Mr. J. Glaisher, Professor C. G. Knott, Professor J. H. Poynting, Mr. Horace Darwin, *and* Dr. R. Copeland (*drawn up by the Secretary*), *appointed for the Investigation of Earth Tremors in this Country.*

APPENDIX	PAGE
I. *Account of Observations made with the Horizontal Pendulum at Nicolaiew. By* Professor S. Kortazzi	155
II. *The Bifilar Pendulum at the Royal Observatory, Edinburgh. By* Professor R. Copeland	158

Mr. H. Darwin's Bifilar Pendulum.

The preliminary trial of the bifilar pendulum last year led to the discovery of one or two possible sources of error, chiefly resulting from alterations in the distribution of temperature near the instrument. In order to eliminate these as far as possible, Mr. Darwin has made several changes in the latest form of the pendulum.[1]

When the gas-jet was kept burning for some time, it was found that the expansion of the tube produced an apparent tilting to the east, *i.e.*, away from the source of heat. As soon as the flow of heat through the instrument became nearly steady, a far more considerable movement of the mirror in the opposite direction became evident, which was perhaps due to the action of convection currents in the surrounding oil.

The expansion of the tube is greatest on the side towards the gas-jet. Its disturbing effect is therefore a maximum when the gas-jet is in a plane at right angles to that in which the silver wire lies. In the new instrument the mirror is held in a frame so that the plane of the mirror is perpendicular to that of the silver wire, and the principal effect of the expansion is merely an inappreciable change in the sensitiveness of the pendulum. At the same time we should expect that this method of mounting the mirror would diminish the disturbing action of convection currents, as the surface exposed to them lies chiefly in a plane at right angles to that in which the movements of the ground are being measured.

In order to avoid any straining of the tube the lever used in determining the angular value of the scale divisions is prolonged above the tilting-screw. To this upper portion is attached a movable weight, which can be adjusted so that the centre of gravity of the lever coincides with the axis of the tilting-screw. The lever is moved by a rocking-arm worked from a distance by a pair of pneumatic bellows.

The instrument rests on three foot-screws, two of which are in a line parallel to the plane of the silver wire. A tangent-screw is connected with these two, so that one can be raised and the other depressed by an equal amount, and so enable the sensitiveness to be varied. A second tangent-screw is attached to the third foot-screw, or 'back-leg,' by means of which the pendulum can be tilted in the plane perpendicular to that of the silver wire, and the spot of light readjusted to the centre of the scale or photographic paper. Both screws are worked from a distance by long wooden rods.

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[1] For the account of these improvements I am indebted to notes supplied by Mr. Darwin. See also a paper, 'Bifilar Pendulum for Measuring Earth-tilts,' *Nature*, vol. l. 1894, pp. 246–249.

A bifilar pendulum, with the changes above described, was erected early this year at the Royal Observatory, Edinburgh. The instrument is also further protected by a cover from heat effects. Dr. Copeland, Astronomer Royal for Scotland, informs me that, with these arrangements, it is not at all affected by momentary changes of temperature.

The Greek Earthquake Pulsations of April 1894.

On April 20 a severe earthquake took place in north-east Greece, causing much damage in several towns and villages. Soon after the news of its occurrence was published I made frequent observations with the bifilar pendulum at Birmingham, and was fortunate enough to watch the greater part of the remarkable series of pulsations proceeding from the second great disturbance, that of April 27. An account of these movements is given in its proper place below.

A few weeks later I received from Dr. von Rebeur-Paschwitz a list of the records of the same pulsations made by the horizontal pendulum at Nicolaiew. As these gave a somewhat greater velocity for the pulsations, it seemed possible that conclusions of some interest might result from an endeavour to trace the pulsations as they spread outwards from their origin. I accordingly wrote to the directors of the leading magnetic and geodynamic observatories on the Continent and in this country, and I am indebted to their courtesy for much information, a summary of which is given below. Additional details relating to the Italian observatories have been extracted from the valuable 'Bollettino Meteorico' (Supplementi 104 and 105) of the 'Ufficio Centrale di Meteorologia e Geodinamica' of Rome.

The total number of shocks belonging to this earthquake series must amount to several hundred. The strongest were those, already mentioned, on April 20 and 27. Both were felt over the whole of Greece. The epicentral areas seem to have been situated in the eparchy of Locris, and probably not far distant from its capital, Atalante. In the estimates of the velocity which follow I have supposed the earthquake pulsations to start from this town, the position of which is 38° 39′ N. lat., 23° 0′ E. long., and about 98 kilometres from Athens. For convenience the recorded times have all been reduced to Greenwich mean time.

Athens (Dr D. Eginitis), 37° 58′ 20″ N., 23° 43′ 48″ E. The earthquakes were registered by Brassart seismoscopes. These are well regulated, so that the times may be regarded as very exact. April 20, 5h. 17m. 5s. P.M., duration 4 seconds; followed by a second shock at 5h. 17m. 35s. P.M., duration 7 seconds. April 27, 7h. 46m. 11s. P.M., a very strong shock, duration 12 seconds.

Catania [1] (Professor A. Ricco), 37° 28′ N., 15° 4′ E. April 20, 5h. 23m. 8s. P.M. April 27, 7h. 47m. 19s. P.M. The photographic record of the normal tromometer shows six series of decreasing oscillations, lasting for about 18 minutes.

Benevento ('Boll. Meteor.'), 41° 8′ N., 14° 45′ E. April 20, 5h. 19m. P.M., a very distinct trace indicated by the Cecchi seismograph. April 27,

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[1] The observatory is situated at a short distance from Catania, but I have been unable to find its exact position. In several cases, the positions of the Italian observatories are only approximate.

7h. 45m. P.M. On both occasions the tromometer oscillated so much that it was not possible to determine the amplitude.

Mineo ('Boll. Meteor.'), 37° 15′ N., 14° 42′ E. April 20, 5h. 26m. (± some seconds), P.M. April 27, 7h. 53m. P.M.

Portici ('Boll. Meteor.'), 40° 50′ N., 14° 19′ E. April 27, 7h. 51m. 9s. P.M., movement indicated by a Brassart seismograph.

Velletri ('Boll. Meteor.'), 41° 41′ N., 12° 47′ E. April 20, 5h. 26m. P.M.

Rocca di Papa (Dr. A. Cancani and 'Boll. Meteor.'), 41° 54′ N., 12° 29′ E. April 20, 5h. 20m. P.M., the beginning of the pulsations indicated by the 'tromometro avvisatore.' The Brassart seismograph displaced at 5h. 22m. ± 20s. April 27, 7h. 45m. P.M., the arrival of the pulsations announced by the 'tromometro avvisatore.' The great seismograph (7 metres in length and 100 kilogrammes in mass) shows the beginning of small earthquakes in the S.E.–N.W. component at 7h. 47m. 30s. At about 7h. 49m. 30s. the large oscillations in the S.E.–N.W. component began, and at 7h. 49m. 49s. in the N.E.–S.W. component. These large oscillations had a period of 7·2 seconds, and present a principal maximum in the N.E.–S.W. component at 7h. 50m. 40s., that of the other component not being well defined. This great undulatory movement ceased at 7h. 57m. 20s. in the N.E.–S.W. component, and at about 8h. 2m. 20s. in the S.E.–N.W. component.

Rome (Professor Tacchini and 'Boll. Meteor.'), 41° 54′ N., 12° 29′ E. April 20, beginning of the movement about 5h. 20m. 20s. P.M. in the N.W.–S.E. component, about 5h. 22m. 0s. in the N.E.–S.W. component. The movement gradually increased until the following maxima were presented: 5h. 25m. 35s., 5h. 26m. 0s., 5h. 26m. 55s. (principal maximum), 5h. 28m. 20s., 5h. 29m. 0s., after which the traces irregularly and slowly decreased, the end of the movement taking place at about 5h. 33m. 15s. in the N.W.–S.E. component, and about 5h. 35m. 10s. in the N.E.–S.W. component. April 27, the beginning of the movement in both components at about 7h. 47m. 50s. P.M.; a series of maxima, first increasing and then decreasing, at 7h. 50m. 55s., 7h. 51m. 40s. (principal maximum), 7h. 52m. 10s., 7h. 52m. 25s., 7h. 53m. 0s., 7h. 53m. 45s, 7h. 55m. 55s., and 7h. 57m. 10s.; the end of the movement in both components may be taken at about 8h. 6m. 20s., but not improbably it was prolonged still further.

Siena ('Boll. Meteor.'), 43° 19′ N., 11° 20′ E. April 20, 5h. 23m. 40s. (± about 10s.) P.M., beginning of the movement in the N.N.E.–S.S.W. component, as registered by the Vicentini seismograph; the oscillations gradually increased in amplitude until they attained the following maxima: between 5h. 25m. 40s. and 5h. 26m. 40s. (two principal maxima), at 5h. 26m. 58s., 5h. 28m. 4s., and 5h. 28m. 40s.; the oscillations then slowly disappeared, the total duration being about fifteen minutes. During the first seven minutes the average period of the oscillations in the E.S.E.–W.N.W. component was about five seconds, and in the other, during the first ten minutes, about four seconds. At about 5h. 49m. 40s. there was a group of fourteen small oscillations, lasting for one minute. April 27, about 7h. 47m. 40s. P.M., beginning of the oscillations, which increased suddenly in amplitude; the first maximum at 7h. 51m.; after which there were four others, the principal maximum being at 7h. 53m. 6s. During an interval of 552 seconds sixty-five oscillations were counted in the N.N.E.–S.S.W. component, and sixty-one in the E.S.E.–W.N.W. component, giving an average period of eight and a half seconds for each complete oscillation.

Florence ('Boll. Meteor.'), 43° 46′ N., 11° 15′ E. April 20, from 5h. 23m. 5s. (± 15s.) to 5h. 28m. 51s. P.M. April 27, 7h. 49m. 2s. to 7h. 50m. 11s. P.M.; movement indicated by the Cecchi seismograph.

San Luca, near Bologna ('Boll. Meteor.'). April 20, 5h. 25m. P.M., a very slight movement indicated by the Bertelli tromometer. It was also indicated by the De Rossi microseismograph.

Spinea, near Mestre-Venezia ('Boll. Meteor.'). April 20, 5h. 25m. 17s. P.M., a movement of about five seconds in duration. April 27, 7h. 49m. 7s., a movement of about four seconds in duration.

Padua ('Boll. Meteor.'), 45° 24′ N., 11° 52′ E. April 20, 5h. 25m. 15s. P.M., a very slight movement, followed by others at 5h. 26m. 15s., 5h. 27m. 55s., 5h. 29m. 25s., and 5h. 30m. 50s. Microseismic movements were indicated by the more delicate apparatus until 5h. 40m. 30s. At 5h. 26m. 15s. the 'Agamennone seismographic pendulum' was started. April 27, shocks at 7h. 50m. 30s., 7h. 51m. 5s., 7h. 51m. 45s., and 7h. 53m. 25s. P.M. The tromometer continued agitated until 10h. 40m. P.M.

Piacenza ('Boll. Meteor.'), 45° 3′ N., 9° 40′ E. April 20, 5h. 28m. (±10–15s.) P.M.

Pavia ('Boll. Meteor.'), 45° 11′ N., 9° 9′ E. April 20, about 5h. 28m. P.M., movement, lasting for 150 seconds, indicated by the Brassart seismograph.

Nicolaiew (Professor Kortazzi, details communicated by Dr. E. von Rebeur-Paschwitz), 46° 58′ 51″ N., 31° 58′ 28″ E. From April 20 the horizontal pendulum was constantly disturbed by the Greek earthquakes. Strong disturbances occurred at the following times:—April 20, 5h. 42m. P.M.; April 21, 4h. 18m. A.M., 8h. 12m. P.M.; April 22, 10h. 32m. A.M.; April 24, 2h. 47m. A.M.; April 25, 0h. 41m. A.M.; April 27, 7h. 49m. P.M. (very strong); April 30, 4h. 24m. A.M.; May 1, 0h. 55m. A.M.

Charkow (Professor G. Lewitzky), 50° 0′ 10″ N., 36° 13′ 40″ E. From April 20, 5h. 23m. P.M. to April 22, 3h. 5m. A.M., the horizontal pendulum was disturbed; April 20, 5h. 25m. P.M., beginning of the strongest movements; April 21, 4h. 21m. A.M., maximum of a shock; 8h. 13m. P.M., beginning of a strong movement; April 27, 7h. 48m. P.M., beginning of the movement. The disturbed state of the pendulum, with a few weak shocks, lasted until April 28, 8h. 23m. A.M.

Potsdam (Dr. Eschenhagen), 52° 22′ 55″ N., 13° 3′ 59″ E. The magnetic curves on April 20 and 27 show distinct traces of the pulsations:—

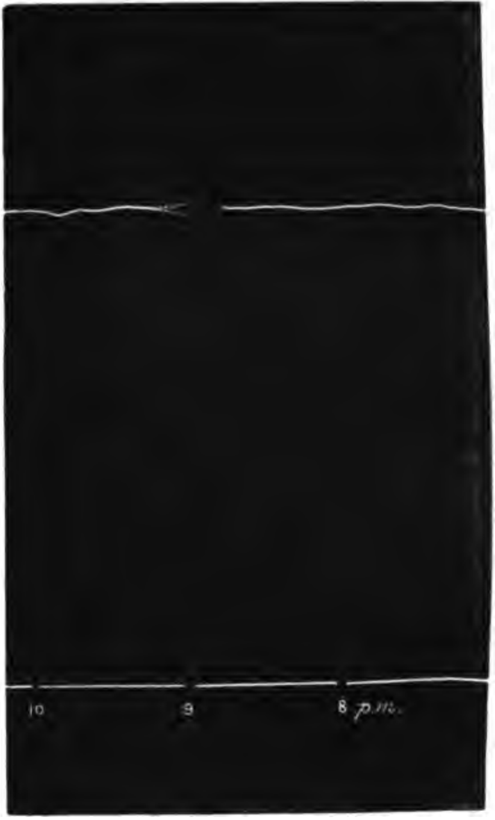
		h. m. s.		h. m. s.			
April 20, Declination	from	5 30 53	to	5 31 41	P.M.,	Ampl.	1′
Horizontal intensity	„	5 31 59	„	5 35 29	„	„	½′
Vertical intensity							
First shock	„	5 30 29	„	5 33 59	„		
Second „	„	5 34 59	„	5 36 29	„	„	½′
April 27, Declination—							
First slight shock,		7 53 50 P.M.,				„	1′
Second principal „	„	7 55 50	to	8 18 50	„	„	5–6′

Swingings on the whole gradually diminishing, but from time to time again increasing.

		h. m. s.		h. m. s.		
Horizontal intensity—						
First shock		7 54 20			Ampl.	1–2′
Second „	from	7 56 20	to	8 1 50	„	3′
Swingings until				8 6 20	„	0′·8
Vertical intensity—						
First shock	from	7 54 50	to	7 58 50		
Second „	„	8 0 20	„	8 3 20		

I am indebted to Dr. Eschenhagen for copies of the six curves. Two of these (those of the declination and horizontal intensity on April 27) are shown in figs. 1 and 2.

FIG. 1.—Potsdam: Declination, April 27, 1894.



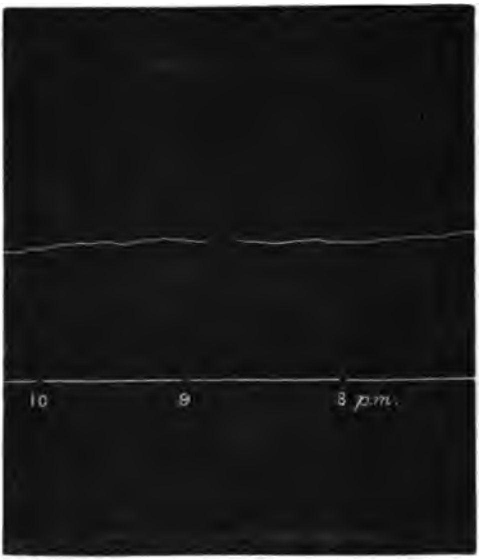
Wilhelmshaven (Dr. C. Börgen), 53° 31′ 52″ N., 8° 8′ 48″ E. The traces on the magnetic curves consist of a slight broadening of the curves. The times read off are those of the beginning of the disturbance in each case.

		h. m.
April 20,	Declination	5 30 P.M.
	Bifilar	no trace.
	Lloyd's Balance	5 30 P.M.
April 27,	Declination	7 55 „
	Bifilar	7 57 „
	Lloyd's Balance	7 57 „

Parc St. Maur (M. Renou and M. Moureaux), 48° 48′ 34″ N., 2° 29′ 38″ E. No trace of any disturbance exists on the magnetic curves on April 20. On April 27 two pulsations are perceptible on the declination curve, the first very feeble at 7h. 54m., the second more marked at 7h. 59m. P.M. The curves of the two components of magnetic force are apparently undisturbed. Two bars of copper with bifilar suspension, orientated N.S. and

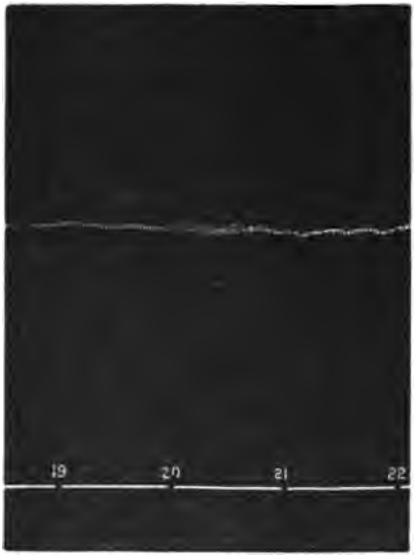
E.W., show not the least sign of any disturbance. 'The movement,' M. Renou remarks, 'is therefore *magnetic* and not *mechanical*.'

FIG. 2.—Potsdam: Horizontal Intensity, April 27, 1894.



Utrecht (M. M. Snellen), 52° 5′ 9″ N., 5° 7′ 55″ E. April 27, the magnetic diagrams show unmistakable traces. For copies of them I am indebted to M. Snellen. That of the declination is reproduced in fig. 3. The following are the times of the beginning of the oscillations:—

FIG. 3.—Utrecht: Declination, April 27, 1894.



		h.	m.	s.
April 27.	Declination	7	57	13·P.M.
	Horizontal intensity	7	56	34 „
	Vertical intensity	7	56	10 „

Kew (Mr. C. Chree), 51° 38′ 6″ N., 0° 18′ 47″ W. ‘There is a very small but unmistakable movement in the horizontal force curve, and a simultaneous extremely slight suggestion of a movement in the declination curve. Careful measurements give 8h. 0m. P.M. as the mean Greenwich time of the middle of the movement on the horizontal force curve, and 7h. 59m. P.M. as that for the declination curve. There is not the faintest trace of movement in the vertical force curve.’

Birmingham, 52° 28′ N., 1° 54′ W. The pulsations were first seen on April 27 at 7h. 59m. P.M. Between 8h. 1m. and 8h. 3m. 20s. the image passed the cross wire twenty times, giving an average duration of 14 seconds for each oscillation. Between 8h. 8m. and 8h. 10m. 2s. the same number of oscillations was completed, the average duration of each being 12·2 seconds. The amplitude was determined by adjusting the image of the disc of light so that at one limit of its movement its edge coincided with the cross-wire of the telescope. At 7h. 59m. the range was equal to three-quarters of the diameter of the disc. The whole diameter, it was afterwards found, is equivalent to 0·98 inch of the scale, so that the trace of the disturbance on a photographic recording apparatus in the same position as the scale would have been 18 mm. in breadth. As the angular value of the scale-divisions had not been ascertained since the beginning of August 1893 a new determination was made on the evenings of May 16–18. The mean of twenty-four pairs of tilts of 2″ is 6·66±·08 inches of the scale. Thus, at 7h. 59m. the range was 0″·22. After this I believe it slightly increased until 8h. 2m. or 8h. 3m. At 8h. 5m. it was 0″·16. It then rapidly and almost continually diminished, being 0″·11 at 8h. 5½m., 0″·08 at 8h. 7m., 0″·05 at 8h. 8m., and 0″·03 at 8h. 12m. The movement then became so small that it could only be estimated. It was about 0″·01 at 8h. 14m., 0″·005 at 8h. 16m. At 8h. 17m. there was a single oscillation of 0″·015. From 8h. 18m. to 8h. 19m. the image was steady, but at the latter time the range suddenly increased to 0″·03, but diminished after a few oscillations, until at 8h. 28m. the image was steady again. After this time no movement so great as 0″·003 could with any certainty be detected.[1]

In addition to the above records it should be stated that the magnetic curves on April 27 have been examined at the following observatories with a negative result: Coimbra, Greenwich, Lisbon, Madrid, Nantes, Nice, and Stonyhurst.

The difference between the distances of Athens and Wilhelmshaven from Atalante is 1,910 km., and the difference between the recorded times at the same places is about 12m. 55s. on April 20, and about 10m. 9s. on April 27. Assuming that these times correspond to the same phase of the disturbance, we obtain 2·46 and 3·14 km. per second respectively for the average velocities on these days. These give :[2]—

Time at epicentrum on April 20 = 5h. 16m. 25s. P.M., G.M.T.
„ „ „ 27 = 7h. 45m. 40s. P.M. „

Using these values of the initial time, we have the following table :—

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[1] Owing to the lag of the mirror through the oil these estimates are probably less than the actual amounts. When the frame of the pendulum is tilted suddenly through an angle of 2″, the image at first moves quickly, but during the first 15 seconds not more than half its total deflection is accomplished.

[2] Since the duration of the disturbance at Athens on April 27 was only 12 seconds,

Place	Distance from epicentrum in km.	Instrument	April 20			April 27		
			Phase of movement	Time-interval in secs.	Velocity in km. per sec.	Phase of movement	Time-interval in secs.	Velocity in km. per sec.
1. Catania . .	707	—	—	403	1·75	—	99	7·15
2. Mineo . .	744	—	—	575	1·29	—	440	1·69
3. Portici . .	775	Brassart seismograph	—	—	—	—	329	2·36
4. Velletri . .	933	—	—	575	1·62	—	—	—
5. Rocca di Papa .	954	'Tromometro avvisatore'	Beginning . .	215	4·44	—	—	—
6. Rocca di Papa .	954	Brassart seismograph	—	335	2·85	—	—	—
7. Rocca di Papa .	954	Great seismograph .	—	—	—	Beginning of small oscillations	110	8·67
8. Rocca di Papa .	954	Great seismograph .	—	—	—	Beginning of large oscillations	230	4·15
9. Rocca di Papa .	954	Great seismograph .	—	—	—	Maximum . . .	300	3·18
10. Rome . .	963	—	Beginning of movement, N.W.–S.E. component	235	4·10	Beginning of movement	130	7·41
11. Rome . .	963	—	Beginning of large oscillations	550	1·75	Beginning of large oscillations	315	3·06
12. Rome . .	963	—	Principal maximum	630	1·53	Principal maximum .	360	2·68
13. Siena . .	1,108	Vicentini micro-seismograph	Beginning of movement	435	2·55	Beginning of movement	120	9·23
14. Siena . .	1,108	Vicentini micro-seismograph	Beginning of large oscillations	555	2·00	Beginning of large oscillations	320	3·46
15. Siena . .	1,108	Vicentini micro-seismograph	Principal maximum	615	1·80	Principal maximum .	446	2·48
16. Florence . .	1,139	—	Beginning of movement	400	2·85	Beginning of movement	202	5·6

17. San Luce (Bologna)	About 1,167	Bertelli tromometer	—	515	2·27	—	—	—
18. Spinea (Mestre Venezia)	About 1,171	—	—	532	2·20	—	207	5·6
19. Padua . .	1,188	—	Beginning of movement	530	2·24	Beginning of movement	390	4·10
20. Padua . .	1,188	Agamennone seismograph	Beginning of movement	590	2·00	—	—	—
21. Piacenza . .	1,313	—	—	695	1·89	—	—	—
22. Pavia . .	1,359	Brassart seismograph	Beginning of movement	695	1·96	—	—	—
23. Nicolaiew . .	1,180	Horizontal pendulum	—	1,535	0·77	—	200	5·90
24. Charkow . .	1,640	Horizontal pendulum	—	215	7·63	—	140	11·71
25. Potsdam . .	1,710	Declination . .	Beginning . .	868	1·97	First slight shock .	490	3·49
26. Potsdam . .	1,710	Declination . .	—	—	—	Beginning of principal movement	610	2·80
27. Potsdam . .	1,710	Horizontal intensity	Beginning . .	934	1·83	First shock . . .	520	3·29
28. Potsdam . .	1,710	Horizontal intensity	—	—	—	Beginning of second shock	640	2·67
29. Potsdam . .	1,710	Vertical intensity .	—	—	—	Beginning of first shock	550	3·11
30. Potsdam . .	1,710	Vertical intensity .	—	—	—	Beginning of second shock	880	1·94
31. Wilhelmshaven .	2,003	Declination . .	Beginning . .	815	2·46	Beginning . . .	560	3·59
32. Wilhelmshaven .	2,003	Bifilar . . .	—	—	—	Beginning . . .	680	2·95
33. Wilhelmshaven .	2,003	Lloyd's balance .	Beginning . .	815	2·46	Beginning . . .	680	2·95
34. Parc St. Maur .	1,989	Declination . .	—	—	—	—	500	3·98
35. Parc St. Maur .	1,989	Declination . .	—	—	—	—	800	2·49
36. Utrecht . .	2,035	Declination . .	—	—	—	Beginning . . .	693	2·94
37. Utrecht . .	2,035	Horizontal intensity	—	—	—	Beginning . . .	654	3·11
38. Utrecht . .	2,035	Vertical intensity .	—	—	—	Beginning . . .	630	3·23
39. Kew . . .	2,326	Declination . .	—	—	—	Middle . . .	800	2·90
40. Kew . . .	2,326	Horizontal intensity	—	—	—	Middle . . .	860	2·70
41. Birmingham .	2,455	Bifilar pendulum .	—	—	—	Beginning observed .	800	3·07

The values of the velocity in this table have been obtained on the supposition that all phases of the disturbance left the origin simultaneously at the initial times given above. This is of course in the highest degree improbable, but it was so taken in the absence of any certainty as to which phase corresponded to these times. It is evident that the discordances between many of the above results must in a great measure be due to this assumption. For instance, on April 27, the beginning of the pulsations was registered at Charkow one minute sooner than at Nicolaiew, though the former place is 460 km. further from the epicentrum. Both stations being observatories, the explanation appears to be that the pendulum at Charkow was affected by earlier pulsations of smaller amplitude.[1]

The most probable estimate of the velocity is, I believe, that derived from the epochs of the beginning of the larger pulsations. Including those obtained from magnetographs, which are not disturbed by the small initial movements, we have the following results[2] for the mean velocity:—

April 20. 2·08 ± ·08 km. per sec.
„ 27. 3·21 ± ·07 km. „

Future Work of the Committee.

The grant of 50*l.* awarded last year to the Committee has been spent in providing for the foundation, &c., of the bifilar pendulum at Birmingham, and (in part) for one of the improved pendulums with photographic recording apparatus, to be placed in that city under the charge of the Secretary.

The Committee consider that it would be desirable to test the working of the pendulum by placing another of similar construction at a short distance from it. The comparison would probably be made for a year, and the second instrument would afterwards be available for use elsewhere. They accordingly request that they be reappointed, with a grant of 100*l.*

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it follows that either (1) the instrument there was only affected by the larger oscillations, or (2) that the rapid vibrations which constitute the earthquake shock were distinct from the pulsations, and that the former alone were registered. The initial times above given were obtained on the supposition that the former alternative is correct. It seems possible, however, that the pulsations are not merely the distant equivalent of the shock, but that they may travel with a different, and probably greater, velocity. If this be the case, the estimates of the velocity may be a little too great.

[1] If the velocity of the pulsations is independent of their amplitude, these small pulsations must have left the origin more than six minutes before the larger ones (as if the earth's crust slowly quivered before giving way), and might possibly be utilised for giving earthquake warnings (see Professor Milne's suggestion in *Seismol. Journ.*, vol. i. 1893, pp. 10–15).

[2] The first of these is calculated from six observations (Nos. 11, 14, 25, 27, 31, 33), the second from thirteen observations (Nos. 8, 11, 14, 26, 27, 29, 31, 32, 33, 36, 37, 38, 41).

APPENDIX I.

Account of Observations made with the Horizontal Pendulum at Nicolaiew.[1]

By Professor S. Kortazzi.

More than a year has elapsed since I began to make observations with the pendulum of M. E. von Rebeur-Paschwitz installed in the cellar of the observatory, but I have not as yet published any detailed reports on this subject, with the exception of a brief account given at one of the meetings of the Astronomical Society at St. Petersburg. . . . The more or less regular oscillations of the pendulum, as well as the abrupt perturbations which it often experiences, depend on several physical agents, and I find it necessary to continue the series of observations for several months to be in a position to obtain from them more or less sound results.

For the present I can only draw some general conclusions :—

(1) The horizontal pendulum may be used as a very sensible and very trustworthy seismograph, which does not fail to record all the oscillations of the ground and tremors of the earth's crust, even in the case of very distant earthquakes. Comparing the results obtained here with those at Strassburg during the first three months of this year, we find more than a dozen disturbances registered at the same time by both instruments.

(2) Different seismic disturbances produce extremely varied movements of the pendulum. On the enclosed copy of the photograph, which registers the positions from April 3, 8h., to April 9, 7h., are shown two feeble disturbances on April 4 at 22h. 40m. and April 6, 5·5h., and a very strong one on April 8 at 4·0h. The latter corresponds to the earthquake which took place at this time in Servia and Southern Hungary. For three-quarters of an hour the pendulum was very strongly disturbed; it even changed abruptly its normal position; and it was only at 6h. that it became steady, whilst no one in the whole country felt then the least movement of the ground. On August 17, however, at $4\frac{3}{4}$h. mean time, a rather pronounced earthquake occurred at Nicolaiew itself, and was observed by a great number of the inhabitants, whilst the pendulum only experienced a feeble disturbance similar to that shown on the curve on April 6 at 10·5h. (but much more feeble), when the pendulum was purposely disturbed by a feeble current of air under its cover.

(3) The pendulum is subject to periodic diurnal and annual oscillations. The amplitude of the former does not on an average exceed $0''\cdot1$, whilst that of the latter attains $3''$ or $4''$. These last changes may be explained by the inclination of the upper layers of the ground produced by the annual changes of temperature at the depth of the pillar; whilst the diurnal oscillations, it seems to me, cannot be explained in the same way, because not only the ground at the depth of 15 feet, at which the pillar of the pendulum is founded, but even the air of the cellar, does not

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[1] Communicated in two letters (dated August 31, 1893, and July 10, 1894) to the Secretary, the second being an abstract of a report to be presented to the Société Astronomique Russe.

experience any changes of temperature throughout the day. On the enclosed copy the diurnal oscillations are shown very distinctly.

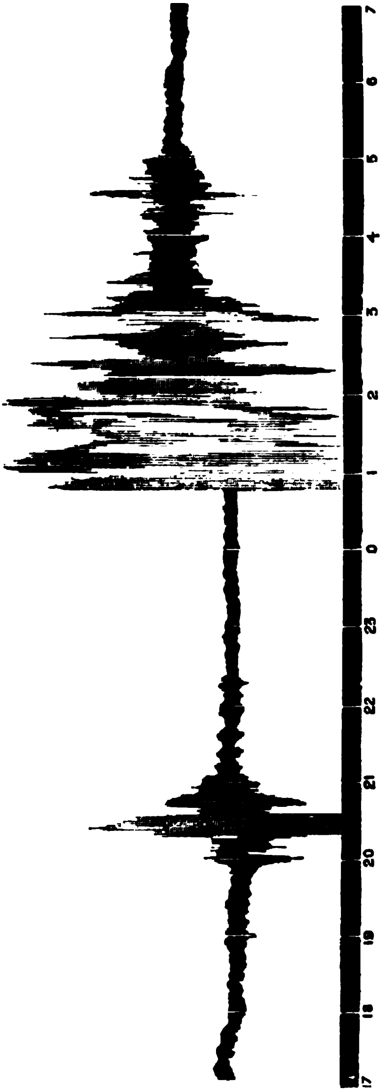


FIG. 4.—Earthquake Disturbances of March 21–22, 1894.

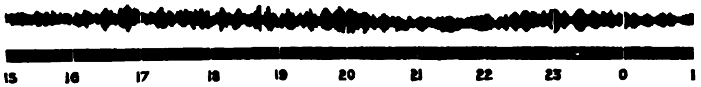
In my letter of August $\frac{16}{28}$, 1893, I pointed out the three principal kinds of movement which the horizontal pendulum experiences: (1) the annual or long-period deviations which M. de Rebeur-Paschwitz calls 'Nullpunctbewegungen;' (2) the diurnal deviations; and (3) seismic disturbances. To these must be added (4) disturbances during storms, probably arising from the movement of the building, producing tremors in the ground; and (5) periodic deviations of short period, in all probability of seismic origin.

The deviations (1) are shown in the continual movement of the pendulum in the same direction, with slight digressions, lasting several months, apparently during the transition from winter to summer, and *vice versâ*. In the present position of my instrument the pendulum inclines towards the south in spring and summer, and towards the north in winter. . . . Here I must remark that the amplitude of the annual changes of temperature in the cellar where the instrument is placed does not exceed 6° R. (13°·5 F.), whilst the changes of the diurnal period are quite insensible.

In fig. 4 are seen two seismic disturbances on March 21–22, 1894. The second of these (beginning at 0h. 43m. Nicolaiew mean time) coincides with the disturbance observed at all the Italian seismic stations, and also registered by the magnetographs of Pola, Potsdam, and Wilhelmshaven (see 'Boll. Meteorico dell' Ufficio centrale . . . al Collegio Romano,' No. 135, Supplemento 103), and was probably produced by the earthquake in Japan (7h. 27m. 49s. Tokio mean time). Four to five hours earlier another rather strong disturbance is seen on the photogram, which does not coincide with any observed earthquake, but which was also registered by the horizontal pendulum at Charkow

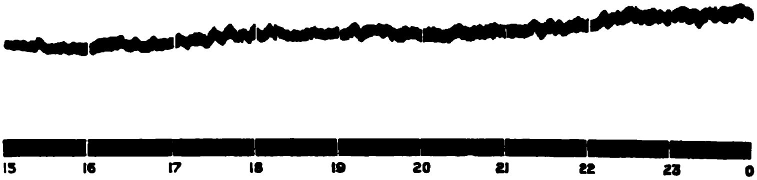
The movements of the pendulum during a storm on May 4, 1893, are represented in fig. 5 (1 mm. = 0″·044).

FIG. 5.—Movements during a Storm on May 4, 1893.



Lastly, fig. 6 (1 mm. = 0″·025) serves to illustrate the deviations (5), when the pendulum, without being agitated, is never at rest, but for several hours inclines sometimes in one direction, sometimes in the other. During the month of March, 1894, such disturbances frequently occurred.

FIG. 6.—Disturbances of Short Period (probably seismic) on March 5, 1894



On the whole, the observations of the horizontal pendulum may be of much service in studying the different movements of the earth's crust and of the ground.

Amongst other things it seems to me difficult to explain the oscillations of the diurnal period observed here, as well as at Potsdam, &c., by M. von Rebeur-Paschwitz, and at Charkow by Professor Lewitzky, since the temperature and relative humidity of the air in the neighbourhood of the instrument remain constant throughout the day.

Having at my disposal an almost uninterrupted series of observations for fifteen months in the same position of the instrument (the axis of the pendulum in the prime vertical), I wished to investigate if the moon produced any influence on these oscillations. For this purpose I divided the whole series into sixty successive groups, corresponding to the different phases of the moon, from which I have drawn the conclusion that the influence of the moon *is insensible*, or, if it exists, that it is masked by the different accidental disturbances. After this, having divided the whole series into five consecutive parts (three lunar months in each), I have obtained the following table of the deviations of the pendulum from its mean position for every two hours (astronomical time) in thousandths of a second[1] (0″·001):—

—	0h.	2	4	6	8	10	12	14	16	18	20	22h.	Amplitude
1893													″
Mar. 14–June 9 .	−10·6	+15·7	+32·0	+39·5	+29·2	+25·8	+11·5	− 5·8	−25·7	−41·4	−41·5	−28·5	0·081
June 10–Sept. 5 .	−38·5	− 9·3	+17·8	+38·2	+42·3	+39·3	+26·6	+10·0	− 8·3	−29·2	−50·1	−45·4	0·092
Sept. 6–Dec. 3 .	−13·2	− 2·0	+10·2	+16·1	+18·7	+18·0	+12·9	+ 4·1	− 7·7	−17·7	−20·5	−19·7	0·039
Dec. 4–Mar. 2 .	− 1·6	+19·8	+25·8	+26·4	+20·7	+11·9	+ 4·5	− 5·0	−12·4	−27·0	−32·7	−27·1	0·059
1894													
Mar. 3–May 30 .	−11·5	+10·7	+28·7	+35·1	+30·3	+25·6	+12·7	− 5·0	−22·6	−37·5	−39·7	−26·8	0·075

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[1] A − sign denotes a deviation to the north, a + sign to the south.

We see, therefore, that the amplitude of the deviations is greatest during the summer months. It will be remarked that the first and last series, corresponding nearly to the same times of the year, give almost identical deviations.

APPENDIX II.

The Bifilar Pendulum at the Royal Observatory, Edinburgh.

By Professor R. COPELAND, *F.R.S.E.*, *Astronomer Royal for Scotland.*

This instrument was placed in position by Mr. H. Darwin on March 23, 1894. It is, with slight exceptions, similar to the instrument erected at Birmingham, in April 1893, for Mr. C. Davison, and which has been fully described in the British Association Report for 1893, pp. 291–303. The exceptions referred to are: (1) the arrangement of the mirror of the Edinburgh instrument at right angles to the plane of the suspending wires, and (2) the surrounding of the instrument by a heavy casing to prevent, as far as possible, any movement of the mirror due to change of temperature resulting from the lighting of the illuminating lamp or other cause.

The whole apparatus, including the scale and lamp, is placed in a hut erected for the purpose over a trench running east and west, formed within the Observatory grounds by removing the soil and levelling the rock. A hole 2 feet deep is bored in the rock near the west end of the trench, and into this is leaded the heavy iron supporting bar. This bar is 1½ inch in diameter, and projects above the surface of the rock sufficiently far to allow the iron plate carrying the instrument to be fixed to it by screws. A slate slab 18 inches square and 1⅛ inch thick, in which a circular hole is cut 9½ inches in diameter, is placed round the iron plate, but not touching it, and is supported on a wooden frame at the level of the plate. On this slate is placed a square cast-iron casing, 6½ inches deep, which surrounds the body of the instrument, including the mirror-box. On this, again, rests a second slate with a circular hole, 6½ inches in diameter, through which passes the head of the instrument and the upper part of the brass tube containing the frame. The head is covered by a stoneware jar resting on the upper slate.

The cast-iron casing surrounding the body of the instrument is perforated by an aperture 4¼ inches in diameter opposite the mirror-window. To prevent undue access of air, and consequent dewing of the window, a truncated cone of sheet copper is fastened inside this aperture, with its smaller end turned inwards towards the instrument. In spite of this precaution, however, much difficulty has been experienced from the dewing of the glass, and a wooden shutter lined with green baize has been arranged to still further prevent the circulation of air. The shutter is raised when necessary by pulling a string from the east end of the hut. In addition vessels containing chloride of calcium have been placed in the hut and inside the cast-iron casing. Much benefit has been derived from these arrangements. The casing is also perforated with holes to admit the handles of the tangent screws and the pipes of the bellows used for ascertaining the number of divisions of the scale corresponding to a known tilt of the instrument. In both cases provision has been made for preventing tremor being conveyed to the instrument by the use of these parts of the apparatus, the whole of such tremor being taken up by the casing.

The scale and small benzoline illuminating lamp are placed at the east end of the hut. A frame, supported in a horizontal position by two strong iron feet fixed by beds of cement laid on the rock, is traversed by the lamp-stand, which carries an index along the edge of the scale. The readings are taken when the image of a wire placed vertically in front of a circular hole in the lamp-screen coincides with the vertical wire in a fixed theodolite. The scale is divided into millimetres, and the effective length of it traversed by the index is 382 mm., and it is distant 10 feet (=3,048 mm.) from the centre of the instrument. If l be the distance of the lamp from the point of the scale which is due east of the mirror, the azimuth, north or south of east, of the normal to the mirror is $\frac{1}{2} \tan^{-1} \frac{l}{3048}$. When $l=191$ this becomes 1° 47′ 35″, and represents the rotation of the mirror to each side of the north and south position within the range of the scale. When the rotation exceeds this amount the mirror has to be brought back to its north and south position by turning the long handle attached to the southern levelling screw.

The plane of the suspending wire is in the east and west direction with the longer section of the wire toward the east; consequently, as the face of the mirror is towards the east, a tilt of the upper support of the wire towards the north produces a corresponding deflection of the normal to the mirror also to the north; hence tilts in the north and south direction only are measured by the instrument.

From measures of the dimensions of the instrument which have been supplied by Mr. Horace Darwin, it is computed that the movement of the lever, attached to the micrometer screw against which the top of the frame is pressed, through the fixed amount of 13 mm. for which the apparatus is set, produces a tilt of 2·016 seconds of arc in the upper support of the suspending wire. As soon as the pendulum was mounted experiments were made to ascertain its sensitiveness, or the scale value of this fixed amount of tilt. The mean of nine measures taken on March 26 gave 62·4 mm. of the scale = 2″·016. This was considered excessive, and steps were taken to reduce it gradually. The mean of four measures made between May 5 and 8 gave 21·2 mm. = 2″·016. Since the last of these dates the two levelling screws, whose combined movement alters the sensitiveness, have not been interfered with. Observations of the sensitiveness have, however, been made occasionally, four measures between May 16 and June 9 giving 19·3 mm., 17·2 mm., 20·0 mm., and 23·7 mm. respectively, or an average of 20·0 mm., equal to 2″·016. Since June 9 four measures have been made, but these give somewhat anomalous and as yet unexplained results.

In the absence of any photographic arrangement for giving a continuous record of the position of the mirror, it has been decided to take readings at each full minute from five minutes before to five minutes after Paris mean noon every day. This has been carried out from May 26 up to the present time, with the exception of a few days, when the readings were rendered impossible by a deposit of moisture on the mirror window or other cause. These observations were made by Mr. T. Heath and Mr. A. J. Ramsay.

On no occasion has any unsteadiness or oscillation of the mirror been observed, though a slight change of position appears to take place during the time of observation, owing possibly to the presence of the observer or the heat of the lamp. This change, however, is very slight, and the mean of the eleven observations of each set is taken as showing the position of the mirror for that day at Paris noon. These mean scale readings have been laid on a curve with the date as one argument and the divisions of the scale as the other. The result shows that the mirror has been constantly turning in azimuth from the east towards the north during the whole period over which the observations have extended (May 26 to July 31). The total amount of this movement has been 517 mm. on the scale in sixty-six days, or an angular rotation of 9° 37′ 23″ for the ray falling on the mirror from the lamp; which is, of course, equivalent to an angular rotation of 4° 48′ 42″ in the mirror itself.

If, now, 20 mm. (=2″·016) be taken as the sensitiveness of the instrument over all this time—though about this number there is some uncertainty—the total tilt of the instrument towards the north appears to have been fifty-two seconds of arc in sixty-six days. The stability of the nadir-point of the mural circle in the adjoining observatory proves that this tilt must either be in the superficial layer of the rock to which the instrument is attached or, which is far more probable, in the pendulum itself.

The experiments confirm the results obtained elsewhere, that the instrument, while unfitted to show the slower progressive tilts of the earth's surface, is pre-eminently suited, by its great sensitiveness and momentary stability, for the indication of earth tremors. However, to bring out the full powers of the apparatus it is obviously necessary to secure a continuous photographic record of the position of the mirror.

M. Antoine d'Abbadie, at whose cost the pendulum was supplied, has caused simultaneous observations to be taken with his 'nadirane' at Abbadia in north latitude 43° 22′·8 and longitude 7m. 0s. west of Greenwich. The readings at the two stations have, however, not yet been compared.

The Electrolytic Methods of Quantitative Analysis.—Report of the Committee, consisting of Professor J. EMERSON REYNOLDS (*Chairman*), Dr. C. A. KOHN (*Secretary*), Professor P. FRANKLAND, Professor F. CLOWES, Dr. HUGH MARSHALL, Mr. A. E. FLETCHER, Mr. D. H. NAGEL, Mr. T. TURNER, *and* Mr. J. B. COLEMAN.

THE first work undertaken by the Committee has been the compilation of the bibliography of the subject, with which some progress has been made.

In addition, the plan on which the experimental part of the work is to be carried out has been arranged. This is to include the investigation of the methods for the determination of the following metals: silver, lead, mercury, bismuth, cadmium, tin, antimony, iron, zinc, manganese; and subsequently of the methods for the separation of these metals both from one another and from other metals.

This is all the Committee undertook to do when they were appointed without a grant of money.

They now ask to be reappointed and with a grant of 40*l*.

Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor H. McLeod, Professor W. C. Roberts Austen, Mr. H. G. Madan, *and* Mr. D. H. Nagel.

The work of searching for, and arranging chronologically under proper heads, the titles of papers on subjects relating to spectroscopy has been proceeded with by the Committee, and a list is appended which brings the catalogue of spectroscopic literature up to the beginning of 1894.

It will be a subject for consideration whether the reappointment of the Committee would be advisable. Considerable difficulty arises in finding any one who can gratuitously devote sufficient time to the work of obtaining and verifying references to papers, and who possesses at the same time the requisite facilities for doing so.

In the meantime, however, the Committee ask to be reappointed for one more year.

PAPERS ON SUBJECTS CONNECTED WITH SPECTROSCOPY.

Continuation of the List published in the Report for 1889.

[In cases where it has not been found possible to verify a reference, the latter is placed in brackets, in the same column as the title of the paper. A list of the chief abbreviations used will be found at the end of the catalogue.]

I.

INSTRUMENTAL.

1881.

W. Wernicke .	Neues Flüssigkeitsprisma für Spectralapparate.	'Zeitschr. f. Instrumentenkunde,' i. 353–357.
N. von Konkoly .	Ein kleines Universalspectroscop ('Centralzeitung f. Opt. u. Mech.' 1881, No. 10).	'Zeitschr. f. Instrumentenkunde,' i. 273.

1882.

" " .	Sternspectralapparat in Verbindung mit einem Colorimeter ('Centr.-Zeit. f. Opt. u. Mech.' 1882, No. 1).	'Zeitschr. f. Instrumentenkunde,' ii. 111–112 (Abs.), 148–149 (Abs.); Beiblätter, vi. 230–231 (Abs.)

1883.

C. Braun . .	Verbessertes Prisma 'à vision directe.' (Read April 23.)	'Ber. Erzb. Haynald'schen Obs. zu Kalocsa in Ungarn,' 1883, 133–138, 'Zeitschr. f. ' Instrumentenkunde,' vii. 399–400 (Abs.); 'Beiblätter,' xii. 335–336 (Abs.)
W. E. Wilson .	A Reflecting Spectroscope. (Roy. Soc. Dublin, Nov. 19.)	'Nature,' xxix. 167 (Abs.)
R. von Kövesligethy	Ueber ein neues Kolorimeter, zugleich Spectralphotometer. ('Centralzeitung f. Opt. u. Mech.' vi. 55.)	—

INSTRUMENTAL, 1885, 1886, 1887, 1888.

1885.

A. König . .	Ein neues Spectralphotometer. (Read May 22.)	'Verh. phys. Gesellsch. Berl.' III. Jahrg. 50–53; 'Nature,' xxxii. 191–192 (Abs.)
Noack . .	Ein einfacher Brenner für monochromatisches Licht. ('Zeitschr. zur Förderung des phys. Unterrichts,' ii. 67–69.)	'Beiblätter,' ix. 739 (Abs.).

1886.

L. Respighi . .	Sullo spettroscopio obbiettivo. (Read Dec. 5.)	'Rend. R. Accad. dei Lincei' [4], ii. (2nd sem.), 315–321; 'Beiblätter,' xi. 701 (Abs.); 'Nature,' xxxv. 405 (Abs.)
C. Braun . .	Projectirter Halbprisma-Spectroscop. Universal-Sternspectroscop.	'Ber. Erzb. Haynald'schen Obs. zu Kalocsa in Ungarn,' 1886, 149–150, 151–159; 'Zeitschr. f. Instrumentenkunde,' viii. 288–289 (Abs.)

1887.

O. Tumlirz . .	Ein einfacher Apparat zur Demonstration der Umkehrung der Natriumlinien. (Feb.)	'Repert. der Phys.' xxiii. 404–405; 'Beiblätter,' xi. 707 (Abs.); 'Zeitschr. f. phys. u. chem. Unterricht,' 33–34 (Abs.)
C. C. Hutchins .	A New Photographic Spectroscope. (July).	'Amer. J. Sci.' xxxiv. 58–59; 'Phil. Mag.' [5], xxiv. 221–234.
N. von Konkoly .	Ein einfacher Apparat zum Ablesen der Spectrallinien an photographirten Spectren. (Nov.)	'Centralzeitung f. Opt. u. Mech.' viii. 241–242; 'Beiblätter,' xii. 45–46 (Abs.)

1888.

" .	Ueber ein Spectroscop 'à vision directe.' (Jan. 1.)	'Centralzeitung f. Opt. u. Mech.' ix. 1–3; 'Beiblätter,' xii. 657 (Abs.)
" .	Ein Siderospectrograph. (Feb.) .	'Centralzeitung f. Opt. u. Mech.' ix. 25–27; 'Beiblätter,' xii. 335 (Abs.)
Th. W. Engelmann .	Das Microspectrometer. (June) .	'Zeitschr. f. wiss. Microskopie,' v. 289–296; 'Archives Néerlandaises.' xxiii. 82–92; 'Beiblätter,' xiii. 216 (Abs.); 'Zeitschr. f. physikal. Chem.' ii. 862 (Abs.)
H. W. Vogel .	Universal-Spectralapparat. (June)	'Zeitschr. f. phys. u. chem. Unterricht,' i. 231; 'Beiblätter,' xiv. 506 (Abs.)

INSTRUMENTAL, 1888, 1889, 1890.

A. Blümel . .	Apparat zur Bestätigung des Snellius'schen Brechungsgesetzes, und zur Bestimmung des Brechungsexponenten von Flüssigkeiten. (Dec.)	'Zeitschr. f. phys. u. chem. Unterricht,' ii. 162–165; 'Beiblätter,' xiv. 762 (Abs.)

1889.

J. S. Ames . .	The Concave Grating in Theory and Practice. (March 27.)	'Phil. Mag.' [5], xxvii. 369–384; 'Beiblätter,' xiii. 673 (Abs.)
Prazmowski . .	Ein Spectroscop. (March) . .	'Zeitschr. f. Instrumentenkunde.' ix. 106 (Abs.); 'Beiblätter,' xiii. 495–496 (Abs.)
Ph. Pellin . .	Réfractomètre de M. A. Dupré. Appareil pour mesurer les indices de réfraction des liquides ou des gaz, construit pour le laboratoire municipal de Paris. (Read April 19.)	'J. de Phys.' [2], viii. 411–415; 'Beiblätter,' xiv. 35–36 (Abs.)
G. Hüfner . .	Ueber ein neues Spectrophotometer. (June 28.)	'Zeitschr. f. physikal. Chem.' iii. 562–571.
H. Ebert . .	Optische Mittheilungen. 1. Ein Spectrograph mit einem Hohlspiegel. 2. Ueber das Absorptionsspectrum des Iods. 3. Ueber das Leuchten der Flammen. 4. Ueber die Anwendung des Doppler'schen Principes auf leuchtende Gasmolecüle. (Read July 7).	'Sitzungsb. phys. - med. Gesellsch. Erlangen,' xxi. 1–8; 'Beiblätter,' xiii. 942–944 (Abs.); 'Zeitschr. f. physikal. Chem.' iv. 579 (Abs.)
N. Piltschikoff .	Réfractomètre à lentille pour liquides. (Sept.)	'J. de Phys.' [2], viii. 416–420.
M. Démichel . .	Nouvel appareil pour la recomposition de la lumière. (Sept.)	'La Nature,' xxxiii. 237–238; 'Zeitschr. f. phys. u. chem. Unterricht,' iii. 90.
A. Dupré . .	Un réfractomètre. ('J. de phys. élémentaire,' 1889, 177–182.)	

1890.

H. Krüss . .	Vorrichtung zur automatischen Einstellung der Prismen eines Spectralapparates auf das Minimum der Ablenkung. (March.)	'Zeitschr. f. Instrumentenkunde,' x. 97–100; 'Beiblätter,' xiv. 505–506 (Abs.)
M. d'Arsonval .	Sur un spectro-colorimètre. (Read April 18.)	'J. Soc. franç. de phys.' 1890, 109–110; 'Chem. News,' lxiv. 293 (Abs.)
H. Krüss . .	Spectralapparat mit automatischer Einstellung der Prismen. (April.)	'Festschr. d. math. Gesellsch. in Hamburg,' 1890, II. Theil, 153–158; 'Zeitschr. f. physikal. Chem.' v. 285 (Abs.); 'Centralzeitung f. Optik u. Mech.' xi. 37–38 (Abs.)

INSTRUMENTAL, 1890, 1891, 1892, 1893.

O. Lohse	Construction eines Sternspectrographen. (April.)	'Centralzeitung f. Optik. u. Mech.' xi. 85–86; 'Beiblätter,' xiv. 588 (Abs.)
F. Scheiner	Apparat zur Verbreitung von photographischen Sternspectren. (May.)	'Astr. Nachr.' No. 2969, 279–282; 'Nature,' xlii. 303 (Abs.)
P. Glan	Ein spectro-saccharimeter. (Sept.)	'Chem. Zeit.' xiv. 1306–1307; 'Zeitschr. f. anal. Chem.' xxx. 212–214 (Abs.)
S. P. Thompson	On the Use of Fluor spar in Optical Instruments. (Sept.)	'Phil. Mag.' [5], xxxi. 120–123.

1891.

L. Mach	Ueber ein Interferenzrefractometer. (Read Nov. 5.)	'Sitzungsb. Akad. Wien.' ci. IIa. 5–10; 'Zeitschr. f. Instrumentenkunde,' xii. 89–93.
C. Féry	Sur un nouveau réfractomètre. (Read Dec. 28.)	'C. R.' cxiii. 1028–1030; 'Nature,' xlv. 239–240 (Abs.); 'Beiblätter,' xvi. 273–274 (Abs.); 'Zeitschr. f. physikal. Chem.' ix. 757 (Abs.)
V. Schumann	Vacuumspectrographie	'Chem. News,' lxiv. 275; 'Beiblätter,' xvi. 278 (Abs.)

1892

E. Pringsheim	Argandlampe für Spectralbeobachtungen. (March.)	'Ann. Phys. u. Chem.' [N.F.], xlv. 426–427; 'Zeitschr. f. physikal. Chem.' ix. 766 (Abs.)
A. Crova	Sur la mesure optique des hautes températures. (Read April 19.)	'C. R.' cxiv. 941–943; 'Beiblätter,' xvii. 316 (Abs.)
H. E. J. G. du Bois	Ein Intensivnatronbrenner. (May.)	'Zeitschr. f. Instrumentenkunde,' xii. 165–167; 'Beiblätter,' xvii. 334–335 (Abs.)
J. Scheiner	Ueber neuere Spectroscopconstructionen. (Nov.)	'Zeitschr. f. Instrumentenkunde,' xii. 365–374; 'Beiblätter,' xvii. 1051–1072 (Abs.)

1893.

C. Féry	Un réfractomètre. (Read March 10.)	'Bull. soc. chim. [3], ix. 244–248; 'Beiblätter,' xviii. 77–78 (Abs.)
H. W. Wiley	Lamp for Constant Monochromatic Flame. (April 13.)	'J. Amer. Chem. Soc.' xv. 121–123; 'Chem. Centralbl.' 1893, II. 514 (Abs.)

F. Schmidt and G. Häusch.	Neuer Helmholtz'scher Farbenmischapparat. (May.)	'Zeitschr. f. Instrumentenkunde,' xiii. 200–204; 'Beiblätter,' xviii. 112–113 (Abs.)
A. König . .	Ein neues Spectralphotometer. (Read June 17.)	'Ann. Phys. u. Chem.' [N.F.], xlvi. 527 (Abs.)
Otto Vogel . .	Ueber die Anwendung der Leuchtgassauerstoffflamme zu spectralanalytischen Mineraluntersuchungen. (Sept.)	'Zeitschr. f. anorg. Chem.' v. 42–62; 'Ber.' xxvi. (Ref.), 1019–1020; 'Beiblätter,' xviii. 84–85 (Abs.); 'J. Chem. Soc.' lxvi. II. 594–595 (Abs.)
E. H. Amagat and F. Jean.	Ein Refractometer.	'Zeitschr. f. anal. Chem.' xxxii. 79 (Abs.); 'Beiblätter,' xv. 33 (Abs.); 'Chem. News,' lxvii. 85 (Abs.)

1894.

A. E. Tutton . .	On an Instrument of Precision for producing Monochromatic Light of any desired Wave-length, and its Use in the Investigation of the Optical Properties of Crystals. (Read Feb. 1.)	'Proc. Roy. Soc.' lv. 111–113 (Abs.)

II.

EMISSION SPECTRA.

1879.

W. W. Jacques .	Distribution of Heat in the Spectra of various Sources of Radiation. (Presented April 9.)	'Proc. Amer. Acad.' [N.S.], vi. 142–163.

1884.

O. Schumann .	Ueber die Farbe und die Helligkeit des electrischen Glühlichtes. (May.)	'Electrotechnische Zeitung,' v. 220–228; 'Zeitschr. für Electrotechnik,' iv. 402 (Abs.); 'Beiblätter,' viii. 532–533 (Abs.)
C. Piazzi Smyth .	Micrometrical Measures of Gaseous Spectra under High Pressure. (Read June 16.)	'Trans. Roy. Soc. Edinb.' xxxii. 415–460; 'Proc. Roy. Soc. Edinb.' xii. 696–702 (Abs.); 'Beiblätter,' ix. 421–422 (Abs.), x. 766–767 (Abs.)
C. Fiévez . .	Recherches sur le spectre de carbone dans l'arc électrique, en rapport avec le spectre de comètes et le spectre solaire. (Read Dec. 6.)	'Mém. Couronnés, Roy. Acad. Belg.' xlvii. 4 pp.; 'Beiblätter,' ix. 631 (Abs.)

1885.

P. T. Clève . .	Recherches sur le Samarium. (Feb.)	'Bull. Soc. Chim.' [2], xliii. 161–172: 'Amer. J. Sci.' [3], xxix. 401 (Abs.); 'Chem. News,' li. 145 (Abs.)

EMISSION SPECTRA, 1885, 1886, 1887.

C. Fiévez	Recherches sur le spectre du carbone dans l'arc électrique, en rapport avec le spectre des comètes et le spectre solaire. (Feb. 7.)	'Bull. Acad. Belg.' [3], ix. 75–79 (Report of M. Stas on the Paper).
A. F. Sundell	Spectralversuche. (May 26.)	'Acta Soc. Scient. Fenn.' (Helsingfors), xv. 197–207; 'Beiblätter,' ix. 788–789 (Abs.)
Föhr	Ein Beitrag zur quantitativen Spectralanalyse. (July 15.)	'Chem. Zeitung,' ix. 1013–1014; 'Ber.' xviii. (Referate), 511 (Abs.)

1886.

B. Hasselberg	Sur le spectre à bandes de l'azote et son origine. (Jan.)	'Mem. Spettroscop. Ital.' xv. 1–3; 'Beiblätter,' xii. 349 (Abs.)
E. Goldstein	Emissionspectra erster Ordnung bei den Haloïden. (Read March 5.)	'Verh. phys. Gesellsch. Berl.' v. 38–41; 'Beiblätter,' xiv. 616–617 (Abs.)
V. Schumann	Das zweite Spectrum des Wasserstoffs.	'Beiblätter,' x. 698–699 (Abs.)
H. Marwin	Methode zur Darstellung der Spectrallinien.	'Laterna Magica,' iii. 6–7; 'Beiblätter,' x. 767 (Abs.)

1887.

H. Deslandres	Loi de répartition des raies et des bandes, commune à plusieurs spectres des bandes. Analogie avec la loi de succession des sons d'un corps solide. (Read April 4.)	'C. R.' civ. 972–976; 'Zeitschr. f. physikal. Chem.' i. 519 (Abs.)
G. Mengarini	Il massimo d' intensità luminosa dello spettro solare. (Nota I., read June 12; Nota II., read June 19.)	'Rend. R. Accad. d. Lincei' [4], iii. 482–489, 566–573; 'Beiblätter,' xi. 705 (Abs.)
C. Fiévez	Nouvelles recherches sur le spectre du carbone. (Read July 2.)	'Bull. Acad. Belg.' [3], xiv. 100–107; 'Beiblätter,' xii. 102–103 (Abs.)
A. Grünwald	Ueber die merkwürdigen Beziehungen zwischen dem Spektrum des Wasserdampfes und den Linienspektren des Wasserstoffs und Sauerstoffs, sowie über die chemische Struktur der beiden letztern, und ihre Dissociation in der Sonnenatmosphäre. (July 17.)	'Astr. Nachr.' cxvii. 199–214; 'Phil. Mag.' [5], xxiv. 354–367; 'Chem. News,' lvi. 186–188, 201–202, 223–224, 232; 'J. Chem. Soc.' lii. 1070–1071 (Abs.); 'Nature,' xxxvi. 501–502 (Abs.); 'Am. J. Sci.' [3], xxxix. 399 (Abs.); 'Beiblätter,' xii. 245–246 (Abs.); 'Zeitschr. f. physikal. Chem.' ii. 38 (Abs.)
A. F. Sundell	Researches on Spectrum Analysis. (July.)	'Phil. Mag.' [5], xxiv. 98–106.

EMISSION SPECTRA, 1887, 1888.

E. F. J. Love.	On a Method of Discriminating Real from Accidental Coincidences between the Lines of Different Spectra: with some Applications. (Read Nov. 26.)	'Proc. Phys. Soc.' ix. 94–100; 'Phil. Mag.' [5], xxv. 1–6; 'J. Chem. Soc.' liv. 542–543 (Abs.); 'Beiblätter,' xii. 348–349 (Abs.); 'Zeitschr. f. physikal. Chem.' ii. 447 (Abs.)
H. W. Vogel	Photographische Aufnahme des Sauerstoffspectrums und Vergrösserung desselbens. (Read Dec. 23.)	'Verh. phys. Gesellsch. Berl.' vi. 142; 'Nature,' xxxvii. 311 (Abs.)
W. H. Julius.	Recherches bolométriques dans le spectre infra-rouge.	'Archives Néerlandaises,' xxii. 310–383.

1888.

A. von Oettingen	Ueber Wasserstoffknallgasexplosion. (Read Jan. 6.)	'Verh. phys. Gesellsch. Berl.' vii. 1 (Notice); 'Nature,' xxvii. 311 (Abs.)
J. Trowbridge and W. E. Sabine.	Wave-lengths of Metallic Spectra in the Ultra-violet. (Read Mar. 14.)	'Proc. Am. Acad.' [N.S.], xv. 288–299; 'Phil. Mag.' [5], xxvi. 342–353; 'J. Chem. Soc.' lvi. 1–2 (Abs.); 'Chem. News,' lviii. 237–239, 247–249; 'Beiblätter,' xiii. 382–383 (Abs.)
H. W. Vogel	Ueber das Spectrum des Cyans und des Kohlenstoffs. (Read April 5.)	'Sitzungsb. Akad. Berl.' 1888, 523–528; 'Verhandl. d. phys. Gesellsch. Berl.' vii. 53–56; 'Beiblätter,' xii. 787–788 (Abs.); 'Nature,' xxxviii. 72 (Abs.)
G. Govi	Dei colori invisibili o latenti dei corpi. (Read May 20.)	'Rend. R. Accad. d. Lincei,' iv. 572–577; 'Beiblätter,' xiii. 502–503 (Abs.)
E. Lommel	Subjective Interferenzstreifen im objectiven Spectrum. (Read June 2.)	'Sitzungsb. Akad. München' (1888), 319–320.
C. Fiévez	Nouvelles recherches sur l'origine optique des raies spectacles, en rapport avec la théorie ondulatoire de la lumière. (Read June 8.)	'Bull. Acad. Belg.' [3], xvi. 81–86; 'Beiblätter,' xii. 852–853 (Abs.)
H. W. Vogel	Spectroscopische Notizen. (Read June 25.)	'Ber.' xxi. 2029–2032; 'Zeitschr. f. physikal. Chem.' ii. 655 (Abs.)
H. Deslandres	Spectres des bandes ultra-violettes des métalloïdes avec une faible dispersion. (July.)	'Ann. Chim. et Phys.' [6], xv. 1–86; 'Zeitschr. f. physikal. Chem.' iii. 139 (Abs.); 'Beiblätter,' viii. 809–810 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectra der Elementen. (Read July 26.)	'Abhandl. Akad. Berl.' 1888, 93 pp.; 'Beiblätter,' xiii. 78–79 (Abs.)

Emission Spectra, 1888, 1889.

E. L. Nichols and W. S. Franklin.	A Spectrophotometric Comparison of Sources of Artificial Illumination. (Read in August.)	'Amer. J. Sci.' [3], xxxviii. 100–114; 'Nature,' xl. 404 (Abs.)
J. Janssen	Sur l'application de l'analyse spectrale à la mécanique moléculaire, et sur les spectres de l'oxygène. (Sept.)	'Brit. Assoc. Rep.' 1888, 547–554; 'Beiblätter,' xiv. 617–618 (Abs.)
E. Budde	Ueber eine neue Entdeckung des Hrn. Janssen, welche sich auf das Sauerstoffspectrum bezieht. (Read Nov. 16.)	'Verh. phys. Gesellsch. Berl.' vii. 89–96; 'Beiblätter,' xiii. 501–502 (Abs.); 'Nature,' xxxix. 168 (Abs.)
V. A. Julius	Over de lineaire spectra der Elementen, en over de dubbellinien in de spectra van Natrium, Magnesium en Aluminium.	'Natuurv. Verh. der k. Akad. Amsterdam,' xxvi. 125 pp. and 11 pp.; 'Beiblätter,' xiii. 496–499 (Abs.)
„	Sur les spectres de lignes des éléments.	'Ann. de l'école polytech. Delft,' v. 1–80.
„	Sur les raies doubles dans les spectres du natrium, du magnésium et de l'aluminium.	'Ann. de l'école polytech. Delft,' v. 118–128.
C. Fiévez	Analyse optique de la flamme d'une bougie.	'Annuaire de l'Obs. de Bruxelles,' 1888, 568–575.

1889.

H. Kayser and C. Runge.	Ueber die im galvanischen Lichtbogen auftretenden Bandenspectrum der Kohle. (Read Feb. 28.)	'Ann. Phys. u. Chem.' [N.F.], xxxviii. 80–90; 'Zeitschr. f. physikal. Chem.' iv. 492 (Abs.)
J. Trowbridge and W. C. Sabine.	On the Use of Steam in Spectrum Analysis. (Feb.)	'Amer. J. Sci.' [3], xxxvii. 114–116.
„ „	Wave-lengths of Metallic Spectra in the Ultra-violet. (March.)	'Chem. News,' lvi. 237; 'Zeitschr. f. physikal. Chem.' iii. 210 (Abs.)
A. E. Bostwick	Preliminary Note on the Absorption Spectra of Mixed Liquids. (June.)	'Amer. J. Sci.' [3], xxxvii. 471–473.
C. C. Hutchins	Notes on Metallic Spectra. (June.)	'Amer. J. Sci.' [3], xxxvii. 474–476; 'Phil. Mag.' [5], xxviii. 73–76; 'Beiblätter,' xiii. 883 (Abs.)
Gouy	Sur l'élargissement des raies spectrales des métaux. (Read June 17.)	'C. R.' cviii. 1236–1238; 'Nature,' xl. 216 (Abs.); 'Chem. News,' lx. 8; 'Beiblätter,' xiii. 677–678 (Abs.)
G. Magnanini	Sullo spettro di emissione della ammoniaca. (Read June 2.)	'Rend. d. R. Accad. d. Lincei' [4], v. 1st sem. 900–908; 'Zeitschr. f. physikal Chem.' iv. 435–440; 'Beiblätter,' xiv. 118–119 (Abs.); 'J. Chem. Soc.' lviii. 97 (Abs.)

EMISSION SPECTRA, 1889, 1890.

H. Ebert . .	Optische Mittheilungen. 1. Ein Spectrograph mit einem Hohlspiegel. 2. Ueber das Absorptionsspectrum des Iods. 3. Ueber das Leuchten der Flammen. 4. Ueber die Andwendung des Doppler'schen Principes auf leuchtende Gasmolecüle. (Read July 7.)	'Sitzungsb. phys.-med. Gesellsch. Erlangen,' xxi. 1–8; 'Beiblätter,' xiii. 942–944 (Abs.); 'Zeitschr. f. physikal. Chem.' iv. 579 (Abs.)
A. Wüllner . .	Ueber den allmählichen Uebergang der Gasspectra in ihren verschiedenen Formen. (Read July 18.)	'Sitzungsb. Akad. Berl.' xxxviii. 793–812; 'Zeitschr. f. physikal. Chem.' iv. 587 (Abs.)
K. R. Koch . .	Ueber die Spectra der Gase bei tiefen Temperaturen. (Aug.)	'Ann. Phys. u. Chem.' xxxviii. 213–216; 'J. Chem. Soc.' lviii. 313 (Abs.)
C. Piazzi Smyth .	Re-examination of the Spectra of Twenty-three Gas-vacuum End-on Tubes, after Six to Ten Years of Existence and Use. (Sept.)	'Chem. News,' lx. 223–224; 'Brit. Assoc. Rep.' 1889, 490 (Abs.); 'Nature,' xl. 584 (Abs.)
T. Thomas and C. Trépied.	Sur l'application des hautes températures à l'observation du spectre de l'hydrogène. (Read Sept. 30.)	'C. R.' cix. 524–525; 'Nature,' xl. 588 (Abs.); 'Chem. News,' lx. 208 (Abs.); 'Beiblätter,' xiv. 39–40 (Abs.)
J. R. Rydberg .	Recherches sur la constitution des spectres d'émission des éléments chimiques. (Read Nov. 12.)	'Handl. Svensk. Vet. Akad.' (Stockholm), xxiii. 155 pp.; 'Phil. Mag.' [5], xxix. 331–337 (Abs.)
K. Angström . .	Étude des spectres infra-rouges de l'acide carbonique et de l'oxyde de carbone. (Recd. Nov. 13.)	'Oefversigt af Kongl. Vet. Akad. Förhandl.' (Stockholm), xlvi. 549–557.
H. Moissan . .	Sur la couleur et sur le spectre du fluor. (Read Dec. 16.)	'C. R.' cix. 937–940; 'Nature,' xli. 214 (Abs.)
A. Wüllner . .	Die allmähliche Entwickelung des Wasserstoffspectrums. (Read Dec. 12.)	'Sitzungsb. Akad. Berl.' 1889, 1113–1119.
H. Kayser and C. Runge.	Ueber die Spectren der Elementen. II. Ueber die im galvanischen Lichtbogen auftretenden Bandenspectren der Kohle. (Pub. at Berlin, 45 pp.)	'Beiblätter,' xiii. 811–812 (Abs.)
R. Hitchcock .	Spectrum Photography in the Ultra-violet ('Amer. Nat. Acad.' 1889).	'Nature,' xl. 44 (title).

1890.

G. Salet . .	Sur la flamme bleue du sel marin, et sur la réaction spectroscopique du chlorure de cuivre. (Feb.)	'Bull. Soc. chim. franç.' [3], iii. 328–329; 'Chem. News,' lxi. 377 (Abs.)
A. S. Herschel .	The Spectrum of Subchloride of Copper. (March.)	'Nature,' xli. 513–514; 'Beiblätter,' xiv. 782 (Abs.)

EMISSION SPECTRA, 1890, 1891.

J. M. Eder	Ueber das sichtbare und ultraviolette Emissionsspectrum schwachleuchtender verbrennender Kohlenwasserstoffe (Swan'sche Spectrum), und der Oxyhydrogenflamme (Wasserdampfspectrum). (April.) (Separate publication, 30 pp.)	'Monatsh. f. Chem.' xi. 151–153; 'Beiblätter,' xiv. 780–781 (Abs.); 'Zeitschr. f. physikal. Chem.' vii. 430–431 (Abs.)
H. Kayser and C. Runge.	Ueber die Linienspectren der Alkalien. (Dritter Abschnitt.) (Read June 5.)	'Abhandl. Akad. Berlin,' 1890, 66 pp.; 'Sitzungsb. Akad. Berl.' 1890, 599–600; 'Ber.' xxiv. [Ref.], 253 (Abs.); 'Phil. Mag.' [5], xxx. 203–204 (Abs.)
J. S. Ames	On some Gaseous Spectra—Hydrogen, Nitrogen. (July.)	'Phil. Mag.' [5], xxx. 48–58.
G. D. Liveing and J. Dewar.	The Spectroscopic Properties of Dust. (Read Nov. 20.)	'Proc. Roy. Soc.' xlviii. 437–440.
V. Schumann	Latest Researches on the Photography of Metallic Spectra. (Dec. 19.)	'Chem. News,' lxii. 299.
W. H. Julius	Die Licht- und Wärmestrahlung verbrannter Gase.	'Gekrönte Preisarbeit des Vereins zur Beförderung des Gewerbfleisses in Deutschland,' 1890, 26 pp.; 'Beiblätter,' xiv. 602–615 (Abs.)

1891.

A. Bettendorf	Studien über die Erden des Cerium- und Yttrium-Gruppe. (Jan.)	'Ann. Chem. u. Pharm.' cclxiii. 164–174; 'Chem. News,' lxiii. 159–160, 172–173.
H. Kayser	Ueber den Ursprung des Banden- und Linienspectrums. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], xlii. 310–318.
G. D. Liveing and J. Dewar.	On the Influence of Pressure on the Spectra of Flames. (Read Feb. 19.)	'Proc. Roy. Soc.' xlix. 217–227; 'Chem. News,' lxiii. 143–145, 155–156 (Abs.); 'Zeitschr. f. physikal. Chem.' viii. 332 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectra der Elemente der zweiten Mendeléjeff'schen Gruppe. (Read Feb. 19.)	'Ann. Phys. u. Chem.' [N.F.], xliii. 385–409; 'Sitzungsb. Akad. Berl.' 1891, I. 177–178 (Abs.); 'Zeitschr. f. physikal. Chem.' viii. 575 (Abs.)
H. Deslandres	Méthode nouvelle pour la recherche des bandes faibles dans les spectres de bandes. (Read Mar. 31.)	'C. R.' cxii. 661–663; 'Nature,' xliii. 552 (Abs.); 'Chem. News,' lxiii. 179–180 (Abs.)
W. N. Hartley	On the Physical Character of the Lines in the Spark Spectra of the Elements. (Read April 16.)	'Proc. Roy. Soc.' xlix. 448–451; 'J. Chem. Soc.' lxiv. II. 2–3 (Abs.)

EMISSION SPECTRA, 1891, 1892.

W. Crookes . .	On Electric Evaporation. (Recd. June 4. Read June 11.)	'Proc. Roy. Soc.' l. 88–105; 'Nature,' xliv. 212–215; 'Chem. News,' lxiii. 287–290.
E. E. Brooks . .	On Terminal Spectra of Electrodes, observed *in vacuo*. (July.)	'Chem. News,' lxiv. 30–31; 'Beiblätter,' xvi. 426 (Abs.)
C. Piazzi Smith .	Report of the Committee appointed to co-operate with Dr. C. Piazzi Smyth in his Researches on the Ultra-violet Rays of the Solar Spectrum. (Aug.)	'Brit. Assoc. Rep.' 1891, 147–148.
B. Hasselberg .	Zur Spectroscopie der Verbindungen. Spectrum der Thonerde. (Read Oct. 14.)	'Handl. K. Svensk. Vet. Akad.' (Stockholm), xxiv. (45 pp.); 'Beiblätter,' xvii. 738–739 (Abs.)
V. Schumann .	Vacuum Spectro-Photography. (Dec. 4.)	'Chem. News,' lxiv. 275.

1892.

H. Moissan . .	Détermination de quelques constantes physiques de fluor. (Jan.)	'Ann. de Chim. et Phys.' [6], xxv. 125–144; 'Nature,' xlv. 260 (Abs.)
J. Parry . .	The Spectrum of Iron and the Periodic Law. (Jan. 14.)	'Nature,' xlv. 253–255.
E. L. Nichols and B. W. Snow.	The Character of the Light emitted by Glowing Zinc Oxide. (Jan.)	'Phil. Mag.' [5], xxxiii. 19–28; 'Beiblätter,' xvi. 427 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectren von Kupfer, Silber und Gold. (Read Jan. 21.)	'Abhandl. Akad. Berlin,' 1892 (39 pp.); 'Ann. Phys. u. Chem.' [N.F.], xlvi. 225–243; 'Chem. News,' lxvii. 49 (Abs.)
A. Grünwald . .	Ueber das sogenannte zweite oder zusammengesetzte Wasserstoffspectrum von Dr. B. Hasselberg, und die Structur des Wasserstoffs. I. Theil. Empirisch-Induction-Abtheilung. (Read Feb. 4.)	'Sitzungsb. Akad. Wien,' ci. II. Abth. 121–254; 'Monatshefte f. Chem.' xiii. 111–244; 'Zeitschr. f. physikal. Chem.' x. 668 (Abs.); 'Beiblätter,' xvii. 203–204 (Abs.); 'J. Chem. Soc.' lxii. 1351 (Abs.)
Lecoq de Boisbaudran.	Recherches sur le samarium. (Read March 14.)	'C. R.' cxiv. 572–577.
J. Violle . .	Sur le rayonnement des corps incandescents, et la mesure optique des hautes températures. (Read Mar. 28.)	'C. R.' cxiv. 734–736; 'Beiblätter,' xvii. 315–316 (Abs.)
E. Pringsheim .	Das Kirchhoff'sche Gesetz und die Strahlung der Gase.	'Ann. Phys. u. Chem.' [N.F.], xlv. 428–459; 'Nature,' xlv. 312 (Abs.)
Lecoq de Boisbaudran.	Sur les spectres électriques du gallium. (Read April 4.)	'C. R.' cxiv. 815–818; 'Beiblätter,' xvi. 532–533 (Abs.); 'J. Chem. Soc.' lxii. 930 (Abs.)

EMISSION SPECTRA, 1892, 1893.

A. Bettendorff	Studien über die Erden der Cerium- und Yttrium-Gruppe. III. Kathodsluminescenz der Gadolinerde. (May.)	'Ann. Chem. u. Pharm.' cclxx. 376–383; 'Beiblätter,' xvi. 744–745 (Abs.)
B. W. Snow	Ueber das ultrarothe Emissionsspectrum der Alkalien. (June.)	'Ann. Phys. u. Chem.' [N.F.], xlvii. 208–251; 'Nature,' xlvii. 39 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectren von Aluminium, Indium und Thallium. (Read July 7.)	'Abhandl. Akad. Berlin,' 1892 (28 pp.)
A. Smithells	Experiments on Flame Spectra. (Read Aug. 5.)	'Brit. Assoc. Report,' 1892, 645–646.
J. M. Eder and E. Valenta.	Ueber einige neue Linien im brechbarsten ultravioletten Emissionspectrum des metallischen Calcium. (Aug.)	'Denkschr. Akad. Wien,' 1892, 252–253; 'Beiblätter,' xvii. 444 (Abs.)
C. Piazzi Smyth	Second Report of the Committee appointed to co-operate with Dr. C. Piazzi Smyth in his Researches on the Ultra-violet Rays of the Solar Spectrum. (Aug.)	'Brit. Assoc. Rep.' 1892, 74–76; 'Beiblätter,' xvii. 829–830 (Abs.)
G. D. Liveing	Note on Plücker's Statement that he has discovered the Line Spectrum of Oxygen in the Oxyhydrogen Flame. (Oct.)	'Phil. Mag.' [5], xxxiv. 371–375; 'Beiblätter,' xvii. 925–926 (Abs.)
L. Arons	Ueber einen Quecksilberlichtbogen. (Read Oct. 21.)	'Ann. Phys. u. Chem.' [N.F.], xlvii. 762–771; 'Nature,' xlvii. 24 (Abs.)
B. Brunhes	Expérience sur les spectres cannelés. (Nov.)	'J. de Phys.' [2], x. 508–512; 'Beiblätter,' xvi. 435–436 (Abs.)
W. N. Hartley	On a Method of Observing the Spectra of easily Volatile Metals and their Salts, and of Separating their Spectra from those of the Alkalies. (Read Dec. 1.)	'J. Chem. Soc.' lxiii. 138–141; 'Chem. News,' lxvi. 313 (Abs.)
G. Krüss and H. Krüss.	Beiträge zur quantitativen Spectralanalyse.	'Zeitschr. f. anorg. Chem.' i. 104–125; 'J. Chem. Soc.' lxiv. II. 283–284 (Abs.)

1893.

J. S. Ames	On the Probable Spectrum of Sulphur. (Jan.)	'Astron. and Astrophys.' xii. 50, 51; 'Beiblätter,' xvii. 827 (Abs.)
J. M. Eder and E. Valenta.	Ueber das Emissionspectrum des Kohlenstoffes und Siliciums. (Read Jan. 19.)	'Denkschr. Akad. Wien,' lx. 241–263; 'Beiblätter,' xviii. 753–756 (Abs.)
H. Wilde	On the Spectrum of Thallium and its Relation to the Homologous Spectra of Indium and Gallium. (Read April 20.)	'Proc. Roy. Soc.' liii. 369–372; 'J. Chem. Soc.' lxiv. II. 525 (Abs.); 'Beiblätter,' xvii. 1054 (Abs.)

EMISSION SPECTRA, 1893.

V. Schumann .	Ueber die Photographie der Lichtstrahlen kleinster Wellenlängen. (April.)	'Sitzungsb. Akad. Wien.' cii. II. 415–475, 625–694; 'Chem. News,' lxviii. 46–47, 56–57, 63, 81–82, 100–101, 133, 158–159, 164–165, 180–181, 194–195, 201, 229, 239–240, 252, 262–263, 289–290, 301, lxix. 9, 34; 'Beiblätter,' xviii. 187–189 (Abs.)
J. M. Eder and E. Valenta.	Ueber das ultraviolette Linienspectrum des elementaren Bor. (Read April 13).	'Denkschr. Akad. Wien,' lx. 307–311; 'Beiblätter,' xviii. 752–753 (Abs.)
D. Cochin . .	Sur les spectres de flammes de quelques métaux. (Read May 8.)	'C. R.' cxvi. 1055–1057; 'Chem. News,' lxvii. 265 (Abs.); 'J. Chem. Soc.' lxiv. II. 402 (Abs.)
E. Pringsheim .	Ueber die Strahlung von Lithium, Thallium und Kalium. (Read May 12.)	'Nature,' xlviii. 144 (Abs.)
E. Carvallo . .	Le spectre calorifique de la fluorine. (Read May 23.)	'C. R.' cxvi. 1189–1191; 'Beiblätter,' xvii. 917–918 (Abs.)
W. N. Hartley .	Flame Spectra at High Temperatures. (Read June 1.)	'Proc. Roy. Soc.' liv. 5–7 (Abs.); 'Nature,' xlviii. 165–166 (Abs.); 'Chem. News,' lxvii. 279 (Abs.); 'Beiblätter,' xvii. 1055–1056 (Abs.)
G. D. Liveing and J. Dewar.	Spectra of the Flames of some Metallic Compounds. (Read June 16.)	'Proc. Roy. Soc.' lii. 117–123; 'J. Chem. Soc.' lxiv. II. 401–402 (Abs.); 'Beiblätter,' xvii. 1056–1057 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectren von Aluminium, Indium und Thallium. (Read July 7.)	'Abhandl. Akad. Berl. 1892, 28 pp.; 'Ann. Phys. u. Chem.' [N.F.], xlviii. 126–149; 'J. Chem. Soc.' lxiv. II. 313 (Abs.)
J. M. Eder and E. Valenta.	Ueber den Verlauf der Bunsen'schen Flammereactionen im ultravioletten Spectrum von Kalium, Natrium, Lithium, Calcium, Strontium, Barium und das Verbindungsspectrum der Borsaüre. (Read July 6.)	'Denkschr. Akad. Wien,' lx. 467–476.
B. W. Snow . .	On the Infra-red Spectra of the Alkalies. (July.)	'Phys. Review,' i. 28–50, 95–97, 221–223.
E. Carvallo . .	Le spectre calorifique de la fluorine. (Read Aug. 7.)	'C. R.' cxvii. 306–307; 'Beiblätter,' xvii. 1046–1047 (Abs.)
J. R. Rydberg .	Contributions à la connaissance des spectres linéaires. (III.) (Read Oct. 11.)	'Oefversigt af K. Vet. Akad. Förh.' (Stockholm), l. 505–520.

J. N. Lockyer	The Photographic Spectrum of Electrolytic Iron. (Read Nov. 23.)	'Proc. Roy. Soc.' liv. 359–361; 'Beiblätter,' xviii. 337–338 (Abs.)
J. R. Rydberg	Contributions à la connaissance des spectres linéaires. (IV.) (Read Dec. 11.)	'Oefversigt af K. Vet. Akad. Förh.' (Stockholm), (1894), l. 677–691.
H. Kayser and C. Runge.	Ueber die ultrarothen Spectren der Alkalien.	'Ann. Phys. u. Chem.' [N.F.], xlviii. 150–157.

1894.

B. W. Snow	On the Continuous Spectrum of Sodium. (Jan.)	'Phys. Review,' i. 296–298.
J. N. Lockyer	On the Photographic Arc-Spectrum of Iron Meteorites. (Read Feb. 15.)	'Proc. Roy. Soc.' lv. 139–140 (Abs.); 'Chem. News,' lxix. 89 (Abs.)
A. de Gramont	Sur les spectres d'étincelle de quelques minéraux. (Read April 2.)	'C. R.' cxviii. 746–748; 'Chem. News,' lxviii. 192–193 (Abs.)
J. Janssen	Sur les spectres de l'oxygène porté aux températures élevées. Méthode électrique pour l'échauffement des gaz. (Read April 9.)	'C. R.' cxviii. 757–769; 'Chem. News,' lxix. 207–208 (Abs.)

III.

ABSORPTION SPECTRA.

1878.

R. Amory	Theory of Absorption Bands in the Spectrum, and its bearing in Photography and Chemistry. (Presented Jan. 9.)	'Proc. Amer. Acad.' [N.S.] v. 216–221.
S. P. Langley	On certain Remarkable Groups in the Lower Spectrum. (Presented Oct. 7.)	'Proc. Amer. Acad.' [N.S.], vi. 92–105.

1880.

W. C. Winlock	On the Group 'B' in the Solar Spectrum. (Presented June 9.)	'Proc. Amer. Acad.' [N.S.], viii. 398–405.

1881.

F. Boas	Beiträge zur Erkenntniss der Farbe des Wassers. (Inaug.-Dissert. Kiel.)	'Beiblätter,' v. 797–799 (Abs.)

1883.

H. W. Vogel	pectrographischer Vergleich von Sonnenlicht und Himmelslicht. (June.)	'Phot. Mittheil.' xx. 74; 'Beiblätter,' vii. 600 (Abs.)

1884.

E. Schoene	Spectrum of Ozone and the Presence of Ozone in the Atmosphere. (In Russian.) (Read May 3.)	'J. Russ. Phys.-Chem. Soc.' xvi. No. 7, pt. ii. 250–252; 'J. Chem. Soc.' xlviii. 713 (Abs.)

ABSORPTION SPECTRA, 1885, 1886, 1887.

1885.

Wl. Tichomiroff	Zur Frage über die spectroscopischen Eigenschaften des Mutterkorns. (Read Jan. 21.)	'Pharm. Zeitschr. für Russland, xxiv. 241–247.
N. Egoroff	Das Absorptionspectrum der Atmosphäre. (In Russian). (Read Sept. 24, O.S.)	'J. Russ. Phys.-Chem. Soc.' xvii. [Phys.], No. 7, p. 229.
A. Tschirch	Untersuchungen über das Chlorophyll.	'Chem. Zeitung,' ix. 1431; 'Zeitschr. f. anal. Chem.' xxv. 279 (Abs.)
W. de W. Abney and R. Festing.	Absorption-spectra Thermograms. (Read Jan. 15.)	'Proc. Roy. Soc.' xxxviii. 77–83; 'J. Chem. Soc.' xlviii. 1175–1176 (Abs.); 'Beiblätter,' xiv. 512 (Abs.)

1886.

P. Sabatier	Spectres d'absorption des chromates alcalins et de l'acide chromique. (Read July 6.)	'Ann. de la Facult. des Sciences' (Toulouse), i. D1–D11; 'C. R.' ciii. 49–52; 'Beiblätter,' xii. 194 (Abs.); 'J. de Phys.' [2], vi. 312–320 (Abs.)
W. Leube	Ueber einen neuen pathologischen Harnfarbstoff. (Nov.)	'Archiv f. path. Anat. und Physiol.' cvi. 418–419; 'Zeitschr. f. anal. Chem.' xxvi. 672 (Abs.); 'Chem. News,' lvii. 231 (Abs.)
A. Hénocque.	L'hématoscopie, méthode nouvelle d'analyse du sang, basée sur l'emploi du spectroscope. (Read Nov. 2.)	'C. R.' ciii. 817–820; 'Ber.' xx. (Ref.), 25 (Abs.)
F. Stenger	Ueber die Bedeutung der Absorptionsstreifen. (Dec.)	'Botan. Zeitung,' 1887, 120–126; 'Annuaire Agron.' xiii. 175–176 (Abs.); 'Beiblätter,' xi. 709–710 (Abs.); 'J. Chem. Soc.' lii. 693 (Abs.)

1887.

W. Ramsay	Undersôhning af pleokroismen och ljusabsorptionen i epidote fro̊n Sulzbachthal. (Read Jan. 12.)	'Bihang till K. Svensk. Vet. Akad. Handl.' (Stockholm), xiii. 1–45; 'Zeitschr. f. Kryst. u. Min.' xiii. 97–134; 'Beiblätter,' xii. 53–55 (Abs.)
K. Olszewski	Ueber das Absorptionsspectrum des flüssigen Sauerstoffs und der verflüssigten Luft. (Read Jan. 20.)	'Sitzungsb. Akad. Wien,' xcv. II. 257–261; 'Ann. Phys. u. Chem.' [N.F.], xxxiii. 570–575; 'Zeitschr. f. physikal. Chem.' ii. 348 (Abs.)
W. Crookes	Genesis of the Elements (Lect. Roy. Inst. Feb. 18).	'Proc. Roy. Inst.' xii. 37–60; 'Chem. News,' lv. 83–88, 95–99.
H. Becquerel.	Sur les variations des spectres d'absorption du didyme. (Read March 14.)	'C. R.' civ. 777–780; 'Zeitschr. f. physikal. Chem.' i. 426 (Abs.)

ABSORPTION SPECTRA, 1887, 1888.

A. Tschirch . .	Untersuchungen über das Chlorophyll. (Read March 16.)	‘Ber. d. bot. Gesellsch.’ v. 128–135; ‘Chem. Centralbl.’ 1887, 669 (Abs.); ‘J. Chem. Soc.’ lii. 1116–1117 (Abs.)
C. A. Macmunn .	On the Chromatology of some British Sponges. (Read March 12.)	‘J. Physiol.’ ix. 1–25; ‘J. Chem. Soc.’ liv. 619–620 (Abs.)
G. Krüss and L. F. Nilson.	Studien über die Componenten der Absorptionspectra erzeugenden seltenen Erden. (Read April 25.)	‘Ber.’ xx. 2134–2171; ‘Zeitschr. f. physikal. Chem.’ ii. 108 (Abs.)
J. Reinke . .	Entsetzung bezüglich der subjectiven Absorptionsbänder.	‘Bot. Zeitung,’ 1887, 271–275; ‘Beiblätter,’ xi. 709–710 (Abs.)
L. Soret . .	Absorption des raies ultra-violettes. (Read Aug. 10.)	‘Arch. de Genève,’ xviii. 344–346; ‘Beiblätter,’ xii. 246–247 (Abs.)
A. E. Nordenskiöld	Om ett enkelt förhållande mellan våglängderna i en del ämnens spektra. (Read Sept. 14.)	‘Oefversigt af K. Vet. Akad. Förhandl.’ (Stockholm), xliv. 471–478.
G. H. Bailey . .	The Absorption Spectra of the Haloid Salts of Didymium. (Read Sept. 6.)	‘Brit. Assoc. Rep.’ 654–655 (Abs.); ‘Nature,’ xxxvi. 570 (Abs.); ‘Beiblätter,’ xiii. 815 (Abs.)
” . .	Die Componenten der Absorptionspectra erzeugenden seltenen Erden. (Oct.)	‘Ber.’ xx. 2769–2770, 3325–3327; ‘Zeitschr. f. physikal. Chem.’ ii. 251, 348 (Abs.)
J. Wollheim . .	Untersuchungen über den Chlorophyllfarbstoff. (Nov.)	‘Bot. Centralblatt,’ xxxii. 310–313; ‘Annuaire Agron.’ xiv. 141–143; ‘J. Chem. Soc.’ liv. 723–724 (Abs.)
Sczelkow . .	Ein Beitrag zur Spectrophotometrie des Blutes. (Dec.)	‘Arch. f. d. gesammte Physiol.’ xli. 373–378; ‘Ber.’ xxi. (Ref.), 746 (Abs.)

1888.

F. Stenger . .	Ueber die Gesetzmässigkeiten im Absorptionsspectrum eines Körpers. (Jan.)	‘Ann. Phys. u. Chem.’ [N.F.], xxxiii. 577–586; ‘Zeitschr. f. physikal. Chem.’ ii. 44 (Abs.)
J. Trowbridge and W. C. Sabine.	The Selective Absorption of Metals for Ultra-Violet Light. (Presented Mar. 14.)	‘Proc. Amer. Acad.’ [N.S.], xv. 299–300; ‘Phil. Mag.’ [5], xxvi. 316–317; ‘Chem. News,’ lviii. 216; ‘Beiblätter,’ xiii. 18 (Abs.)
G. Linossier . .	Sur la recherche spectroscopique du sang. (Read March 24.)	‘Bull. Soc. Chim.’ xlix. 691–694; ‘J. Chem. Soc.’ lix. 1139–1140 (Abs.); ‘Chem. News,’ lviii. 37 (Abs.)

ABSORPTION SPECTRA, 1888, 1889.

G. Krüss . .	Beziehung zwischen die Zusammensetzung und Absorptionsspectrum organischer Verbindungen. (May.)	'Zeitschr. f. physikal. Chem.' ii. 310–337.
J. Wollheim . .	Ueber die photographischen Eigenschaften des Chlorophyll. (July.)	'Phot. Mittheil.' xxv. 113, 114; 'Beiblätter,' xii. 856 (Abs.)
C. Liebermann .	Ueber die Spectra der Aether der Oxyanthrachinone. (Aug.)	'Ber.' xxi. 2527; 'Zeitschr. f. physikal Chem.' ii. 967 (Abs.)
G. D. Liveing and J. Dewar.	The Absorption Spectrum, Luminous and Ultra-Violet, of Large Masses of Oxygen. (Sept.)	'Phil. Mag.' [5], xxvi. 286–290; 'Zeitschr. f. physikal. Chem.' ii. 862 (Abs.)
K. Katayama .	Ueber eine neue Blutprobe bei der Kohlenoxydvergiftung. (Oct. 2.)	'Arch. f. Anat. u. Physiol.' cxiv. 53–64; 'Chem. News,' lxi. 241.
B. Hasselberg .	Untersuchungen über das Absorptionspectrum des Iodgases. (Read Nov. 1.)	'Mém. de l'Acad. Imp. des Sciences de St.-Pétersbourg,' xxxvi. No. 17, 50 pp.; 'Nature,' xxxix. 518 (Abs.)
F. B. Pitcher . .	The Absorption Spectra of certain Blue Solutions. (Nov.)	'Amer. J. Sci.' [3], xxxvi. 332–336; 'J. Chem. Soc.' lvi. 325 (Abs.); 'Nature,' xxxix. 70 (Abs.); 'Beiblätter,' xiii. 218 (Abs.)
W. P. Mason . .	Fatal Poisoning by Carbon Monoxide. (Characteristic absorption spectrum of blood.) (Dec.)	'J. Amer. Chem. Soc.' x. 176–178; 'Chem. News,' lix. 260–261.
C. A. Macmunn .	On the Hæmatoporphyrin of *Solecurtus strigillatus.*	'J. Physiol.' viii. 384–390; 'J. Chem. Soc.' liv. 304–305 (Abs.)
Ferry de la Bellone	Nouveau procédé pour découvrir les taches de sang ('Rép. de Pharm.')	'J. de Pharm.' [5], xvii. 253–255; 'J. Chem. Soc.' liv. 1140 (Abs.)
L. Hermann . .	Notiz betreffend das reducirte Hämoglobin.	'Arch. f. d. gesammte Physiol.' xliii. 435; 'Ber.' xxii. (Ref.), 595 (Abs.)

1889.

P. Schottländer .	Vorschlag zur Abänderung des Spetroskops zur Bestimmung des Extinktionskoefficienten absorbirender Körper nach Vierordt's Methode. (Jan.)	'Zeitschr. f. Instrumentenkunde,' ix. 98–101; 'Beiblätter,' xiii. 672–673 (Abs.)
W. Grosse . .	Ueber Messungen der Lichttransmission und Lichtabsorption. (Jan.)	'Zeitschr.' f. Instrumentenkunde,' ix. 1–9; 'Beiblätter,' xiii. 679 (Abs.)
W. Zopf . .	Ueber Pilzfarbstoffe. (Feb.)	'Bot. Zeitung,' 1889, 53–61, 69–81, 85–92; 'Chem. Centr.' [4], i. 291–293 (Abs.); 'J. Chem. Soc.' lvi. 919 (Abs.)
J. Trowbridge and W. C. Sabine.	On the Use of Steam in Spectrum Analysis. (Feb.)	'Phil. Mag.' [5], xxvii. 139–141.

ABSORPTION SPECTRA, 1889.

H. Becquerel . .	Sur les spectres d'absorption de l'épidote. (Read Feb. 11.)	'C. R.' cviii. 282–284; 'Beiblätter,' xiii. 680–681 (Abs.)
W. J. Russell and W. J. Orsman.	The Relation of Cobalt to Iron as indicated by their Absorption Spectra. (Read Feb. 7.)	'Proc. Chem. Soc.' No. 62, 14–15; 'Nature,' xxxix. 453–454 (Abs.); 'Chem. News,' lix. 93–94 (Abs.)
C. Fiévez and E. van Aubel.	Note sur l'intensité lumineuse des bandes d'absorption des liquides colorés. (Read Feb. 2.)	'Bull. Acad. Belg.' [3], xvii. 102–104; 'Arch. de Genève,' [3], xxi. 231–234; 'Beiblätter,' xiii. 501 (Abs.)
E. Bamberger and F. Bordt.	Weitere Beiträge zur Kenntniss des α-Tetrahydronaphtylamins. (Recd. March 11.)	'Ber.' xxii. 625–634; 'J. Chem. Soc.' lvi. 715–717 (Abs.)
G. D. Liveing and J. Dewar.	Notes on the Absorption Spectra of Oxygen and some of its Compounds. (Recd. May 23. Read June 6.)	'Proc. Roy. Soc.' xlvi. 222–230; 'Nature,' xl. 212–214; 'Beiblätter,' xiii. 946–947 (Abs.); 'Ber.' xxiii. (Ref.), 4 (Abs.); 'J. Chem. Soc.' lviii. 675 (Abs.)
A. Babès . .	Note sur quelques matières colorantes et aromatiques produites par le bacille pyocyanique. (Read June 22.)	'C. R. de la Soc. biol.' [9], i. 438–440; 'J. Chem. Soc.' lviii. 189–190 (Abs.)
G. Magnanini .	Sullo spettro di absorbimento del cloruro di nitrosile. (Read June 2.)	'Atti d. R. Acc. d. Lincei,' Rend. [4], v. (1st sem.), 908–911; 'Zeitschr. f. physikal. Chem.' iv. 427–428; 'Ber.' xxiii. (Ref.), 171 (Abs.); 'J. Chem. Soc.' lviii. 97 (Abs.); 'Beiblätter,' xiv. 619 (Abs.)
A. E. Bostwick . .	Preliminary Notice on the Absorption Spectra of Mixed Liquids. (June.)	'Amer. J. Sci.' [3], xxxvii. 471–473; 'Beiblätter,' xiii. 814–815 (Abs.)
H. Ebert . .	Optische Mittheilungen. 1. Ein Spectrograph mit einem Hohlspiegel. 2. Ueber das Absorptionsspectrum des Iods. 3. Ueber das Leuchten der Flammen. 4. Ueber die Anwendung des Doppler'schen Principes auf leuchtende Gasmolecüle. (Read July 7.)	'Sitzungsb. phys.-med. Gesellsch. Erlangen,' xxi. 1–8; 'Beiblätter,' xiii. 942–944 (Abs.); 'Zeitschr. f. physikal. Chem.' iv. 579 (Abs.)
G. Krüss and H. Moraht.	Zur spectrocolorimetrischen Eisen- bezw. Rhodan-Bestimmung. (Read Aug. 6.)	'Ber.' xxii. 2054–2060; 'Zeitschr. f. physikal. Chem.' iv. 585 (Abs.); 'Beiblätter,' xiv. 40 (Abs.)
M. Althausse and G. Krüss.	Beziehung zwischen Zusammensetzung und Absorptionsspectrum organischer Verbindungen. (Read Aug. 6.)	'Ber.' xxii. 2065–2070; 'Zeitschr. f. physikal. Chem.' iv. 585 (Abs.); 'J. Chem. Soc.' lvi. 1093–1094 (Abs.); 'Chem. News,' lx. 240–241 (Abs.); lxi. 209 (Abs.); Beiblätter,' xiii. 945–946 (Abs.)

ABSORPTION SPECTRA, 1889, 1890.

L. Macchiati	Die Farbstoffe der Zapfen von *Abies excelsa*. (Nov.)	'Naturw. Rundschau,' iv. 608; 'Chem. Centr.' [4], ii. Bd. i. 164 (Abs.); 'J. Chem. Soc.' lviii. pt. i. 641–642 (Abs.)
K. Heumann and H. Rey.	Ueber Farbstoffe aus der Gruppe der Benzeïne. (Recd. Nov. 14.)	'Ber.' xxii. 3001–3004; 'Beiblätter,' xiv. 281 (Abs.)

1890.

J. L. Soret and A. Rilliet.	Recherches sur l'absorption des rayons ultra-violets par diverses substances. (Read Jan. 20.)	'Archiv de Genève,' xxiii. 5–69; 'Rev. générale des Sciences,' i. 57 (Abs.); 'Chem. News,' lxii. 202 (Abs.)
F. Schütt	Ueber Peridineënfarbstoffe. (Jan.)	'Ber. d. deutsch. bot. Gesellsch.' viii. 9–32; 'Chem. Centr.' [4], ii. 767–768 (Abs.); 'J. Chem. Soc.' lviii. 1172–1173 (Abs.)
T. L. Patterson	The Quantitative Estimation of Colouring Matters by means of their Absorption Spectra. (Jan.)	'J. Soc. Chem. Industr.' ix. 36–41; 'Zeitschr. f. anal. Chem.' xxxi. 192 (Abs.)
G. Hüfner	Ueber das Gesetz der Dissociation des Oxyhämoglobins und über einige sich daran knüpfende wichtige Fragen aus der Biologie.—Ueber die Bedeutung der in der vorigen Abhandlung vorgetragenen Lehre für die Spektroskopie und Photometrie des Blutes. (Feb.)	'Arch. f. Anat. u. Physiol.' 1890 (Physiol. Abth.), 1–30; 'Zeitschr. f. physikal. Chem.' v. 86 (Abs.)
T. Araki	Ueber den Blutfarbstoff und seine näheren Umwandlungsproducte. (March.)	'Zeitschr. f. physiol. Chem.' xliv. 405–415; 'Zeitschr. f. anal. Chem.' xxix. 737 (Abs.); 'Chem. News,' lxiv. 113 (Abs.)
C. Michie Smith	On the Absorption Spectra of certain Vegetable Colouring Matters. (Read March 17.)	'Proc. Roy. Soc. Edinb.' xvii. 121–137; 'Nature,' xli. 573 (Abs.); 'Beiblätter,' xiv. 619 (Abs.)
C. Liebermann and F. Haber.	Ueber Bidioxymethylenindigo. (Recd. May 24.)	'Ber.' xxiii. 1566–1567; 'J. Chem. Soc.' lviii. 1140 (Abs.)
H. W. Vogel	Ueber farbige Gläser für Dunkelkammerfenster. (May.)	'Phot. Mittheil.' xxvii. 51–52; 'Beiblätter,' xiv. 704 (Abs.)
B. Hasselberg	Untersuchungen über die Absorptionsspectrum des Broms. (Read Oct. 8.)	'Handl. K. Svensk. Vet. Akad.' (Stockholm), xxiv. (53 pp.); 'Beiblätter,' xviii. 339 (Abs.)
W. N. Hartley	The Spectra of Blue and Yellow Chlorophyll, with some Observations on Leaf-Green. (Read Nov. 20.)	'J. Chem. Soc.' lix. 106–124; 'Nature,' xliii. 262 (Abs.)

ABSORPTION SPECTRA, 1890, 1891.

H. Bremer . .	Einfluss der Temperatur gefärbter Lösungen auf die Absorptionsspectrum desselben. (Inaugural-Dissertation, Erlangen, 1890.)	'Zeitschr. f. physikal. Chem.' viii. 430 (Abs.)

1891.

H. Rigollot . .	Sur les spectres d'absorption des solutions d'iode. (Read Jan. 5.)	'C. R.' cxii. 38–40; 'Nature,' xliii. 264 (Abs.); 'Chem. News,' lxiii. 50 (Abs.); 'Zeitschr. f. physikal. Chem.' vii. 335 (Abs.)
K. Olszewski . .	Ueber das Absorptionsspectrum und über die Farbe des flüssigen Sauerstoffes. (Read Jan. 20.)	'Bull. internat. de l'Acad. des Sciences de Cracovie,' 1891, No. 1, 44–46; 'Ann. Phys. u. Chem.' [N.F.], xlii. 662–665; 'Phil. Mag.' [5], xxxi. 447 (Abs.); 'Nature,' xliii. 498 (Abs.)
J. Conroy . .	On the Change in the Absorption Spectrum of Cobalt-Glass produced by Heat. (Read Feb. 13.)	'Phil. Mag.' [5], xxxi. 317–320; 'Proc. Phys. Soc.' xi. 103–106; 'Chem. News,' lxiii. 105 (Abs.)
T. L. Phipson .	Palmelline and Aspergilline. (March 27.)	'Chem. News,' lxiii. 165.
G. Hüfner and E. Albrecht.	Ueber die Durchlässigkeit des Wassers für Licht von verschiedener Wellenlänge. (March.)	'Ann. Phys. u. Chem.' [N.F.], xlii. 1–17; 'Nature,' xliii. 520 (Abs.)
G. Krüss . .	Beiträge zur Chemie des Erbiums und Didyms. (I.) April.)	'Ann. Chem. u. Pharm.' cclxv. 1–27; 'Chem. News,' lxiv. 65–66, 75–76, 99–101, 120–121.
W. M. Watts . .	Index of Spectra	'Phil. Mag.' [5], xxxi. 486 (Review).
J. G. Macgregor .	On the Variation with Temperature and Concentration of the Absorption Spectra of Aqueous Solutions of Salts. (Read May 29.)	'Proc. and Trans. Roy. Soc. Canada,' ix. Sect. III. 27–41; 'Zeitschr. f. physikal. Chem.' x. 430 (Abs.)
E. Schunck . .	Contributions to the Chemistry of Chlorophyll. Part IV. (Read June 18.)	'Proc. Roy. Soc.' l. 302–317; 'J. Chem. Soc.' lxiv. I. 41–42 (Abs.)
E. Vogel . .	Ueber die Lage der Absorptionstreifen und Lichtempfindlichkeit organischer Farbenstoffe.	'Ann. Phys. u. Chem.' [N.F.], xliii. 449–492; 'Zeitschr. f. physikal. Chem.' viii. 569 (Abs.)
R. E. Schmidt and L. Gattermann.	Ueber Oxyderivative des Alizarin-Blau.	'J. prakt. Chem.' xliv. 103–109; 'Chem. News,' lxiv. 261 (Abs.)
O. Knoblauch .	Absorptionsspectralanalyse sehr verdünnter Lösungen.	'Ann. Phys. u. Chem.' [N.F.], xliii. 738, 783; 'Chem. News,' lxiv. 120 (Abs.)
G. Magnanini .	Sul potere assorbente dei sali colorati in rapporto colla dissociazione elettrolitica. (Read Nov. 22.)	'Rend. R. Accad. d. Lincei,' vii. II. 356–363; 'Beiblätter,' xvi. 427–428 (Abs.)

Absorption Spectra, 1891, 1892.

H. Bremer	Ueber den Einfluss der Temperatur gefärbter Lösungen auf die Absorptionsspectren desselben. (Inaug.-Dissert. Erlangen, 1891.)	'Zeitschr. f. anorg. Chem.' i. 112–122 (Abs.); 'Chem. News,' lxvi. 41–42 (Abs.)

1892.

W. L. Dudley	The Colours and Absorption Spectra of Thin Metallic Films, and of Incandescent Vapours of the Metals; with some Observations on Electrical Volatility. (March.)	'Amer. Chem. J.' xiv. 185–190; 'Chem. Centralbl. 1892, II. 23–24 (Abs.); 'Beiblätter,' xvii. 123 (Abs.)
A. H. Church	Researches on Turacin. Part II. (Read April 28.)	'Proc. Roy. Soc.' li. 399–400 (Abs.); 'J. Chem. Soc.' lxiv. I., 184 (Abs.)
E. L. Nichols and B. W. Snow.	On the Selective Absorption of Light by Optical Glass and Calc Spar. (April.)	'Phil. Mag.' [5], xxxi. 379–382; 'Beiblätter,' xvi. (Abs.)
W. Merkelbach	Zur Absorption des Lichtes durch Natriumdampf. (June.)	'Zeitschr. f. phys. u. chem. Unterr.' v. 253; 'Beiblätter,' xvii. 564 (Abs.)
A. Brun	Note sur le spectre d'absorption des grenats almandines rouges de Ceylan. (Read July 7.)	'Arch. de Genève' [3], xxviii. 410–412; 'Beiblätter,' xvii. 335 (Abs.)
T. Ewan	The Absorption Spectra of some Copper Salts in Aqueous Solution. (July.)	'Phil. Mag.' [5], xxxiii. 317–342; 'Zeitschr. f. physikal. Chem.' ix. 750 (Abs.)
A. B. Griffiths	Sur la matière colorante du *micrococcus prodigiosus*. (Read Aug. 8.)	'C. R.' cxv. 321; 'Chem. News,' lxvi. 149–150 (Abs.)
G. D. Liveing and J. Dewar.	Spectrum of Liquid Oxygen, and Refractive Indices of Liquid Oxygen, Nitrous Oxide, and Ethylene. (Aug.)	'Phil. Mag.' [5], xxxiv. 205–209; 'J. Chem. Soc.' lxiv. II. 201–202 (Abs.); 'Beiblätter,' xvii. 121–122 (Abs.)
J. Janeček	Die Grenzen der Beweiskraft des Hämatinspectrums und der Häminkrystalle (Teichmann's Krystalle) für die Anwesenheit von Blut. (Separate publication.)	'Chem. Centralbl.' 1892, i. 507–508 (Abs.); 'J. Chem. Soc.' lxii. 1169–1170 (Abs.)
G. Bider	Ueber das spectroscopische Verhalten des Blutes, nach Aufnahme von schädlichen Gasen, und eine Methode diese Veränderung für gerichtliche Zwecke objectiv zur Darstellung zu bringen.	'Arch. de Pharm.' ccxxx. 609–640; 'Ber.' xxvi. (Ref.), 248–249 (Abs.)
O. Hammarsten	Ueber den Nachweis von Hämatoporphyrin im Harn.	'Skand. Archiv f. Physiol.' iii. 319; 'Zeitschr. f. anal. Chem.' xxxi. 233–235 (Abs.); 'J. Chem. Soc.' lxii. 1136 (Abs.)
J. Janeček	Gerichtlich-chemischer Nachweis von Blut.	'Zeitschr. f. anal. Chem.' xxxi. 236–237 (Abs.); 'Chem. News,' lxvi. 32 (Abs.)

ABSORPTION SPECTRA, 1892, 1893.

W. H. Julius	Bolometrisch onderzoek van absorptiespectra.	'Verhandl. K. Vet. Akad. Amsterdam,' i. 1–49.
P. Dittrich	Das Spectrum des Methämoglobins.	'Arch. f. exper. Pathol. u. Pharmakol.' xxix. 247; 'Zeitschr. f. anal. Chem.' xxxi. 593 (Abs.)
V. Svejcar	Das umgekehrte Natriumspectrum ('Zeitschr. math. phys. Böhm.' xxi. 238.)	'Beiblätter,' xvi. [82] (title).
K. Ångström	Untersuchungen über die spectrale Vertheilung der Absorption im infrarothen Spectrum ('Physikal. Revue,' i. 597–623).	'Beiblätter,' xvii. 332–334 (Abs.)
C. Grebe	Ueber Azofarbenspectra	'Zeitschr. f. physikal. Chem.' x. 673–698.

1893.

F. Zecchini	Sul potere rifrangente del fosforo. II. Potere rifrangente degli acidi del fosforo e dei loro sali sodici. (Read Jan. 8.)	'Rendic. R. Accad. Roma' [5], ii. 1st sem. 31–38.
W. Lapraik	Ueber die Absorptionsspectra einiger Chromverbindungen. (Mar.)	'J. prakt. Chem.' [2], xlvii. 305–342; 'Beiblätter,' xvii. 650–652 (Abs.); 'J. Chem. Soc.' lxiv. II. 313-314 (Abs.)
K. Ångström and W. Palmer.	Le spectre infra-rouge du chlor, et de l'acide hydrochlorique. (Read June 7.)	'Oefversigt af K. Vet. Akad. Förh.' (Stockholm), 1893, 389–395; 'Beiblätter,' xviii. 87 (Abs.)
E. L. Nichols	A Study of the Transmission Spectra of certain Substances in the Infra-Red. (July.)	'Phys. Review,' i. 1–18; 'Beiblätter,' xvii. 1062 (Abs.)
G. Magnanini and T. Bentivoglio.	Intorno allo spettro di absorbimento delle soluzioni di alcuni chromoossalati della serie bleu. (Read July 2.)	'Rendic. R. Accad. Roma' [5], ii. 2nd sem. 17–23.
E. Vogel	Ueber die Lage der Absorptionsstreifen und Lichtempfindlichkeit organischer Farbstoffe. (July.)	'Ann. Phys. u. Chem.' [N.F.], xliii. 449–472; 'Chem. News,' lxvii. 61 (Abs.)
C. Camichel	Sur l'absorption de la lumière dans le brome liquide. (Read Aug. 7).	'C. R.' cxvii. 307–309; 'J. Chem. Soc.' lxiv. II. 561 (Abs.); 'Nature,' xlviii. 384 (Abs.)
G. P. Menegazzi	Spectroscopic Researches on Blood which has been decomposed by the action of Poisonous Gases ('Instit. chim. pharm. d. R. Accad. di Padova, Lavori,' 1892–3).	'Ber.' xxvii. (Ref.), 272–273 (Abs.)
G. Krüss	Ueber die Erbinerde	'Zeitschr. f. anorg. Chem.' iii. 353–369; 'J. Chem. Soc.' lxiv. II. 376. (Abs.)

K. Hofmann and G. Krüss.	Ueber die Holminerde . . .	'Zeitschr. f. anorg. Chem.' iii. 407–414; 'J. Chem. Soc.' lxiv. II. 466–467 (Abs.)
P. Dittrich and T. Araki.	Das Spectrum des Methämoglobins.	'Arch. f. exper. Pathol. u. Pharmakol.' xxix. 247; 'Zeitschr. f. anal. Chem.' xxxi. 593 (Abs.); 'Chem. News,' lxvii. 61 (Abs.)
F. Struve . .	Zur gerichtlich-chemischen Untersuchung verdächtiger Flecken auf Blut.	'Zeitschr. f. anal. Chem.' xxxii. 174–178; 'Chem. News,' lxvii. 308–309.

1894.

G. B. Rizzo . .	Sulle proprieta delle linee e delle bande negli spettri d'assorbimento.	'Il nuovo cimento' [3], xxxv. 132–136; 'Chem. News,' lxix. 222–223 (Abs.)

IV.

PHYSICAL RELATIONS.

1878.

G. S. Hall . .	Colour - Perception. (Presented Mar. 14.)	'Proc. Amer. Acad.' [N.S.], v. 402–413.

1881.

S. P. Langley .	The Bolometer and Radiant Energy. (Read Jan. 12.)	'Proc. Amer. Acad.' viii. 342–358; 'Ann. Chim. et Phys.' [5], xxiv. 275–284; 'Amer. J. Sci.' [3], xxi. 187–198 (Abs.)
A. G. Bell . .	Upon the Production of Sound by Radiant Energy. (Read April 21.)	'Amer. J. Sci.' [3], xxi. 463–490; 'Phil. Mag.' [5], xi. 510–528.

1883.

S. P. Langley .	Experimental Determination of Wave-Lengths in the Invisible Prismatic Spectrum. (April.)	'Mem. Nat. Amer. Acad.' (Washington), ii. 149–162.
G. Buzzolini . .	Sulla condicione di minima e massima deviazione d' un raggio che attraversa un prisma. (Oct.)	'Riv. Sc. Industr.' xv. 302–306.
A. Abt . . .	Beobachtung dunkler Interferenzstreifen im Spectrum des weissen Lichtes ('Naturwiss. Ver. zu Klausenberg,' 1883, 165).	'Beiblätter,' vii. 899–901 (Abs.)

1884.

A. König and C. Dieterici.	Die Empfindlichkeit des Auges für Wellenlängenunterschiede des Lichtes. (Part. I. read Feb. 22; Part II. read March 7.)	'Verh. phys. Gesellsch. Berl.' iii. 7–10; 15–16; 'Nature,' xxix. 496, 568 (Abs.)
G. Sieben . .	Ueber die Abhängigkeit der Brechungsexponenten anomaldispergirender Medien von der Concentration der Lösung und der Temperatur. (April.)	'Ann. Phys. u. Chem.' [N.F.], xxiii. 312–343.

Physical Relations, 1884, 1885, 1886.

H. W. Vogel . .	Ueber die photographische Aufnahme farbiger Körper in den richtigen Helligkeitsverhältnissen. (Read May 23.)	'Verh. phys. Gesellsch. Berl.' iii. 28–32; 'Nature,' xxx. 188 (Abs.)
A. König . .	Ueber die bisher gemachten Bestimmungen der Wellenlängen einfacher complementärer Farben. (Read June 13.)	'Verh. phys. Gesellsch. Berl.' iii. 37–39; 'Nature,' xxx. 308 (Abs.)

1885.

„ . .	Ueber den Gesichtsinn der Zulu-Kaffern. (Read Feb. 13.)	'Verb. Gesellsch. phys. Berl.' iv. 15–17; 'Nature,' xxxi. 476 (Abs.)
J. M. Eder . .	Spectrographische Untersuchung von Normal-Lichtquellen und die Brauchbarkeit der letzteren zu photochemischen Messungen der Lichtempfindlichkeit. (Read April 23.)	'Sitzungsb. Akad. Wien,' xci. II. 1097–1102; 'Monatsh. f. Chem.' vi. 363–368; 'Wiener Anz.' 1885, 93 (Abs.)
H. Kayser . .	Ueber verschiedene Arbeiten über Beziehungen zwischen den Spectrallinien. (Read June 11.)	'Verh. phys. Gesellsch. Berl.' iii. 55 (notice); 'Nature,' xxxii. 312 (Abs.)
J. H. Gladstone .	On the Specific Refraction and Dispersion of the Alums. (Read June 27.)	'Proc. Phys. Soc.' vii. 194–200; 'Phil. Mag.' [5], xx. 162–168.
S. P. Langley .	Observations of Invisible Heat Spectra, and the Recognition of hitherto Unmeasured Wave-Lengths. (Aug.)	'Proc. Amer. Assoc.' xxxiv. 55–75; 'Phil. Mag.' [5], xxi. 394–409; 'Amer. J. Sci.' [3], xxxi. 1–12; 'Nature,' xxxiii. 426 (Abs.)
A. König . .	Ueber einen Fall pathologisch entstandener Violettblindheit. (Read Nov. 6.)	'Verh. phys. Gesellsch. Berl.' iv. 65–69; 'Nature,' xxxiii. 288 (Abs.)

1886.

A. E. Dolbear .	On the Conditions that determine the Length of the Spectrum. (Presented Feb. 10.)	'Proc. Amer. Acad.' [N.S.], xiii. 361–362.
A. König . .	Ueber weitere Beobachtungen an einen durch Alkoholismus gestörten Farbensystem. (Read April 2.)	'Verh. phys. Gesellsch. Berl.' v. 58 (notice).
W. Ramsay . .	Methode zur Bestimmung der Brechungsexponenten in Prismen mit grossen brechenden Winkeln. (Read June 9.)	'Bihang till K. Svensk. Vet. Akad. Handl.' xii. Afd. II. No. 4 (18 pp.); 'Zeitschr. f. Kryst. u. Min.' xii. 209–221; 'Beiblätter,' xi. 439–440 (Abs.)
P. Garbe . .	Recherches expérimentales sur le rayonnement. (Thèse de doctorat, 91 pp., Paris, 1886.)	'J. de Physique,' V. 245–268 (Abs.); 'Beiblätter,' xii. 342–344 (Abs.)

PHYSICAL RELATIONS, 1887.

1887.

O. Lummer	Ueber eine neue Methode Meter und Kilogramm zu vergleichen, die Wellenlänge als Urnormale einzuführen, und über hydrostatische Wägungen. (Read Jan. 21.)	'Verh. phys. Gesellsch. Berl.' vi. 5–11; 'Nature,' xxxv. 432 (Abs.)
R. Nasini	Sulla refrazione molecolare delle sostanze organiche dotate di forte potere dispersivo. (Jan.)	'Rend. R. Accad. d. Lincei' [4], iv. 128–133, 164–172; 'Zeitschr. f. physikal. Chem.' i. 422 (Abs.)
C. E. af Klercker	Sur la dispersion anormale de la lumière. (Read Feb. 9.)	'Ofversigt af Kongl. Svensk. Vet. Akad. Forhandl. Stockholm,' 1887, No. 2, 39 (title only).
W. de W. Abney	Sunlight Colours. (Lect. Roy. Inst., Feb. 25.)	'Proc. Roy. Inst.' xii. 61–71; 'Nature,' xxxv. 498–501; 'Beiblätter,' xii. 350–351 (Abs.)
W. von Bezold	Ueber eine neue Methode zur Zerlegung des weissen Lichtes in Complementenfarben. (Read Mar. 4.)	'Verh. phys. Gesellsch. Berl.' vi. 28.
H. W. Vogel	Ein Mischfarben-Experiment. (Read Mar. 4.)	'Verh. phys. Gesellsch. Berl.' vi. 28–29.
H. A. Rowland	On the Relative Wave-Lengths of the Lines of the Solar Spectrum. (March.)	'Phil. Mag.' [5], xxiii. 257–265.
L. Bell	The Absolute Wave-Length of Light. Parts I. II. (April.)	'Amer. J. Sci.' [3], xxxv. 265–282, 347–367; 'Phil. Mag.' [5], xxv. 245–263, 350–372; 'Nature,' xxxvii. 623 (Abs.)
A. König	Ueber Newton's Gesetz der Farbenmischung. (Read May 6.)	'Verh. phys. Gesellsch. Berl.' vi. 55 (notice).
H. Dufet	Sur les volumes moléculaires et l'énergie réfractive des phosphates, arséniates et hypophosphates de soude. (Read May 20.)	'J. Soc. franç. de Phys.' 1887, 117–128; 'J. de Phys.' [2], vi. 301–312; 'Ber.' xx. (Referate), 530 (Abs.); 'Beiblätter,' xiii. 701–703 (Abs.)
"	Études expérimentales sur la dispersion des axes d'élasticité optique dans quelques cristaux clinorhombiques. (Read July 21.)	'Bull. Soc. Min. de France,' x. 214–230; 'Beiblätter,' xii. 530 (Abs.)
J. W. Bruhl	Ueber den Einfluss der einfachen und der sogenannten mehrfachen Bindung der Atome auf das Lichtbrechungsvermögen der Körper. (July.)	'Zeitschr. f. physikal. Chem.' i. 307–361.
A. E. Nordenskiöld	Sur un rapport simple entre les longueurs d'onde des spectres. (Read Nov. 21.)	'C. R.' cv. 988–995; 'Zeitschr. f. physikal. Chem.' ii. 245 (Abs.)

PHYSICAL RELATIONS, 1887, 1888.

Nanny Lagerborg .	Études sur la variation des indices de réfraction et de la densité du sel gemme sous l'influence de la température. (Read Dec. 14.)	'Bihang till Kongl. Svensk. Vet. Akad. Handlingar,' xiii. Afd. I. No. 10 (12 pp.); 'Beiblätter,' xiii. 490–491 (Abs.)
H. Ebert . .	Ueber den Einfluss der Schwellenwerte der Lichtempfindung auf dem Character der Spectra. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xxxiii. 136–155; 'Zeitschr. f. physikal. Chem.' ii. 250 (Abs.)
" . .	Ueber den Einfluss der Dicke und Helligkeit der strahlenden Schicht auf das Aussehen des Spectrums. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xxxiii. 155–158.
" . .	Empfindliche und bequeme Methode zur Messung der Fortpflanzungsgeschwindigkeit des Lichtes.	'Tageblatt d. 60 versammt. d. deutsche Naturf. und Aerzte zu Wiesbaden' (1887), 42; 'Nature,' xxxvii. 328 (Abs.)

1888.

E. Bertrand . .	Liquides d'indices supérieures à 1·8. (Read Jan 12.)	'Bull. Soc. Min. de France,' xi. 31.
T. Pelham Dale .	On the Numerical Relation between the Index of Refraction and the Wave-Length within a Refractive Medium, and on the Limit of Refraction. (Read Feb. 11.)	'Proc. Phys. Soc.' ix. 167–181; 'Phil. Mag.' [5], xxv. 325–338; 'Beiblätter,' xiii. 805–806 (Abs.)
A. Kundt . .	Ueber die Brechungsexponenten der Metalle. (Feb.)	'Sitzungsb. Akad. Berl.' 1888, 255–272; 'Phil. Mag.' [5], xxvi. 1–18.
K. Feussner . .	Bestimmung der Winkel und Brechungsexponenten von Prismen mit Fernrohr und Scala. (Feb.) ('Sitzungsb. d. Gesellsch. zur Förd. d. Naturwiss. Marburg.' 65–76.)	'Beiblätter,' xiii. 807 (Abs.)
P. Simon . .	Expérience de cours. [Platinum wire heated by current before slit of spectroscope.] (Feb.)	'J. de Phys.' [2], vii. 79–80; 'Beiblätter,' xii. 346 (Abs.)
H. Deslandres .	Détermination, en longueurs d'onde, de deux raies rouges du potassium. (Read Mar. 12.)	'C. R.' cvi. 739; 'Zeitschr. f. physikal. Chem.' ii. 434 (Abs.)
E. Blasius . .	Das Gesetz von Christiansen und die optischen Beobachtungen am Tabaschir. (March.)	'Zeitschr. f. Kryst. u. Min.' xiv. 258–259; 'Beiblätter,' xii. 782 (Abs.)
S. P. Langley	Energy and Vision. (Read April 19.)	'Phil. Mag.' [5], xxvii. 1–23; 'Beiblätter,' xiii. 162–163 (Abs.)
J. Kanonnikoff .	Relations between the Specific Rotatory and the Refractive Power of Chemical Compounds. Part I. (in Russian.) (April.)	'J. Russ. Phys.-Chem. Soc.' xx. No. 6, 571–578; 'J. Chem. Soc.' lvi. 826 (Abs.)

Physical Relations, 1888.

R. Weegmann	Ueber die Molecularrefraction einiger gebrannten Aethane und Aethylene, und über den gegenwärtigen Stand der Landolt-Bruhl'schen Theorie. (Inaugural-Dissertation.) (April.)	'Zeitschr. f. physikal. Chem.' ii. 218–240, 257–269.
A. König	Measurement of the Intensities of Light in the Spectrum ('Arch. f. Anat. u. Physiol,' May 11, 1888).	'Nature,' xxxviii. 119–120 (Abs.)
H. Vogel	Spectroscopische Notizen. (Read June 14.)	'Ber.' xxi. 2029–2032; 'Zeitschr. f. physikal. Chem.' ii. 655 (Abs.)
H. Ebert	Die Methode der höher Interferenzen, und ihre Verwendbarkeit für die Zwecke der qualitativen Spectralanalyse. (Habilitationsschrift, Erlangen, 1888.)	'Zeitschr. f. physikal. Chem.' ii. 434 (Abs.)
A. Haschek	Ueber Brechungsexponenten trüber Medien. (Read July 19.)	'Sitzungsb. Akad. Wien,' xcvii. II. Abth. a. 958–960; 'Monatshefte f. Chem.' ix. 900–902; 'J. Chem. Soc.' lvi. 197 (Abs.); 'Beiblätter,' xiii. 492–493 (Abs.)
W. Sutherland	Molecular Refraction. (Australian Assoc. for Advancement of Science.) (Aug.)	'Phil. Mag.' [5], xxvii. 141–155; 'J. Chem. Soc.' lvi. 454–455 (Abs.); 'Ber.' xxii. (Referate), 129 (Abs.); 'Zeitschr. f. physikal. Chem.' iii. 364 (Abs.)
W. Uhthoff	Ueber die zur Erzeugung eben merklicher Farbendifferenzen erforderlichen Aenderungen der Wellenlänge spectralen Lichtes. (Read Aug. 3.)	'Arch. f. Anat. u. Physiol.' (phys. Abth.), 1889, 171–172; 'Nature,' xxxviii. 464 (Abs.)
E. L. Nichols and W. S. Franklin.	A Spectrophotometric Comparison of Sources of Artificial Illumination. (Aug.)	'Amer. J. Sci.' [3], xxxviii. 100–114.
W. H. Julius	Recherches bolométriques dans le spectre infra-rouge. (Sept.)	'Arch. néerland.' xxii. 310–383; 'Zeitschr. f. physikal. Chem.' ii. 763 (Abs.)
J. Kanonnikoff	Relations between the Specific Rotatory and the Refractive Power of Chemical Compounds. Part II. (in Russian.) (Oct.)	'J. Russ. Phys.-Chem. Soc.' xx. No. 9, part i. 686–693; 'J. Chem. Soc.' lvi. 453–454 (Abs.)
T. Pelham Dale	On the Upper Limit of Refraction in Selenium and Bromine. (Read Nov. 10.)	'Proc. Phys. Soc.' x. 17–23; 'Phil. Mag.' [5], xxvii. 50–56; 'Chem. News,' lviii. 252–253 (Abs.); 'Beiblätter,' xiii. 805–806 (Abs.)
E. Ketteler	Experimentaluntersuchungen über das Refractionsvermögen der Flüssigkeiten zwischen sehr entfernten Temperaturgrenzen. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], xxxii. 662–699; 'Zeitschr. f. physikal. Chem.' iii. 130 (Abs.)

PHYSICAL RELATIONS, 1888, 1889.

Ç. Soret . . .	Recherches sur la réfraction et la dispersion dans les aluns crystallisés. (Deuxième mémoire.) (Dec.)	'Arch. de Genève' [3], xx. 517–536; 'Beiblätter,' xiii. 669–670 (Abs.)
E. Lommel . .	Phosphorophotographie des ultrarothen Spectrums. (Read Dec. 1.)	'Sitzunsb. d. Akad. München' (1888), 397–403.
J. Stössel . .	Ueber die Lichtemission des glühenden Platins.	'Züricher Vierteljahresschrift,' 1888, 308–322; 'Beiblätter,' xiii. 945 (Abs.)
P. Szymański . .	Schulversuche über die Zurückwerfung und Brechung des Lichtes.	'Zeitschr. f. phys. u. chem. Unterricht,' ii. 62–65; 'Beiblätter,' xiv. 763–764 (Abs.)

1889.

A. König . .	Ueber die Abhängigkeit der Sehschärfe von der Lichtintensität bei spectraler Beleuchtung. (Read Jan. 25.)	'Verhandl. phys. Gesellsch. Berlin,' viii. No. 2, 9–12; 'Nature,' xxxix. 408 (Abs.)
W. Grosse . .	Ueber Messungen der Lichttransmission und Lichtabsorption. (Jan.)	'Zeitschr. f. Instrumentenkunde,' ix. 1–9; 'Beiblätter,' xiii. 679 (Abs.)
H. W. Vogel . .	Photographien vom Beugungspectrum. (Read Feb. 8.)	'Verhandl. phys. Gesellsch. Berlin,' viii. No. 3, 20; 'Nature,' xxxix. 480 (Abs.)
F. L. Perrot . .	Vérification expérimentale de la méthode de M. Charles Soret pour la mesure des indices de réfraction des cristaux à deux axes. (Read Feb. 7.)	'Arch. de Genève,' xxi. 113–115; 'C. R.' cviii. 137–138; 'Beiblätter,' xiii. 317 (Abs.)
H. Rubens . .	Die selective Reflexion der Metalle. (Read Mar. 8.)	'Verhandl. phys. Gesellsch. Berlin,' viii. No. 5, 23 (Abs.); 'Ann. Phys. u. Chem.' [N.F.], xxxviii. 249–268; 'Nature,' xxxix. 552 (Abs.)
E. Conrady . .	Berechnung der Atomrefractionen für Natriumlicht. (Mar.)	'Zeitschrift f. physikal. Chem.' iii. 210–227; 'J. Chem. Soc.' lvi. 661 (Abs.)
T. Pelham Dale .	On a Relation existing between the Density and Refraction of the Gaseous Elements, and also some of their Compounds. (Read May 25.)	'Proc. Phys. Soc.' x. 189–192; 'Phil. Mag.' [5], xxviii. 268–271; 'Nature,' xl. 143 (Abs.); 'Chem. News,' lix. 276 (Abs.); 'Beiblätter,' xiii. 937 (Abs.); 'J. Chem. Soc.' lviii. 201 (Abs.)
H. A. Rowland .	Table of Standard Wave-Lengths. (May.)	'Johns Hopkins Univ. Circ.' viii. 69, 78; 'Phil. Mag.' [5], xxvii. 479–484; 'Beiblätter,' xiii. 677 (Abs.)

PHYSICAL RELATIONS, 1889.

J. L. Soret and E. Sarasin.	Sur l'indice de réfraction de l'eau de mer. (Read June 17.)	'C. R.' cviii. 1248-1249; 'Arch. de Genève,' xxi. 509-514; 'Beiblätter,' xiii. 669 (Abs.)
P. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques. (Read June 17.)	'C. R.' cviii. 1249-1251; 'Zeitschr. f. physikal. Chem.' iv. 478 (Abs.)
Lord Rayleigh .	On the Visibility of Faint Interference Bands. (June.)	'Phil. Mag.' [5], xxvii. 484-486.
H. Ebert . .	Optische Mittheilungen. (Physikal-medizin. Soc. Erlangen. July.)	'Zeitschr. f. physikal. Chem.' iv. 578 (Abs.)
B. Walter . .	Ueber die Brechungsexponenten von Salzlösungen. (July.)	'Ann. Phys. u. Chem.' [N.F.], xxxviii. 107-118; 'Zeitschr. f. anal. Chem.' xxix. 430 (Abs.); 'Chem. News,' lxiii. 201 (Abs.); 'J. Chem. Soc.' liii. 202 (Abs.)
T. Costa . .	Sulla correlazione tra il potere rifrangente ed il potere dispersivo dei derivati aromatici a catene laterali sature. (Aug.)	'Gazz. chim. ital.' xix. 478-498; 'Zeitschr. f. physikal. Chem.' v. 280 (Abs.); 'J. Chem. Soc.' lviii. 1201-1202 (Abs.)
C. V. Zenger . .	La spectrophotographie des parties invisibles du spectre solaire. (Read Sept. 9.)	'C. R.' cix. 434-436; 'Beiblätter,' xiv. 37-38 (Abs.)
A. A. Michelson and E. W. Morley.	The Feasibility of Establishing a Light Wave as the ultimate Standard of Length. (Sept.)	'Amer. J. Sci.' [3], xxxviii. 181-186; 'Nature,' xl. 562 (Abs.)
K. Seubert . .	Einige physikalische Constanten von Halogensubstitutionsproducten des Benzols und Toluols. (Read Oct. 14.)	'Ber.' xxii. 2519-2524.
J. H. Gladstone and W. H. Perkin.	On the Correspondence between the Magnetic Rotation and the Refraction and Dispersion of Light by Compounds containing Nitrogen. (Read Nov. 7.)	'J. Chem. Soc.' lv. 750-759.
C. Pulfrich . .	Ueber das Brechungsvermögen von Mischungen zweier Flüssigkeiten. (Nov. 29.)	'Zeitschr. f. physikal. Chem.' iv. 561-569; 'Beiblätter,' xiv. 273 (Abs.)
J. Kanonnikoff .	On the Relations between the Refractive and the Rotatory Powers of Chemical Compounds. (Nov.)	'J. Russ. Phys.-Chem. Soc.' xxii. 85-96; 'Ber.' xxiii. [Ref.], 317-319 (Abs.)
M. Le Blanc . .	Optisch.-chemische Studien mit Berücksichtigung der Dissociationtheorie. (Nov.)	'Zeitschr. f. physikal. Chem.' iv. 553-560; 'J. Chem. Soc.' lviii. 213 (Abs.); 'Beiblätter,' xiv. 272 (Abs.)
E. Fleischl von Marxow.	Ueber die zweckmässigste Herstellung monochromatischen Lichtes. (Nov.)	'Ann. Phys. u. Chem.' [N.F.], xxxviii. 675-676; 'J. Chem. Soc.' lviii. 549 (Abs.)

PHYSICAL RELATIONS, 1889, 1890.

C. Bender . .	Brechungsexponenten normalen Salzlösungen. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xxxix. 89–96; 'Zeitschr. f. physikal. Chem.' v. 283 (Abs.)
J. Seyffart . .	Ueber eine Methode zur Bestimmung der Rotationsdispersion circularpolarisenden Substanzen. (Inaugural-Dissertation.)	'Ann. Phys. u. Chem.' [N.F.], xli. 113–134; 'Zeitschr. f. physikal. Chem.' vi. 590 (Abs.)
K. Angström . .	Nyere studien öfvn det ultrarode Spectrum ('Svensk Kemisk Tidskrift,' 1889, 98–108).	'Beiblätter,' xiv. [27] (title).
W. Kouriloff . .	Terpenes from the Oil of *Pinus abies*.	'J. Russ. Phys.-Chem. Soc.' xxi. 357–367; 'J. Chem. Soc.' lviii. 789 (Abs.)

1890.

E. Abbe. . .	Ueber die Verwendung des Fluorits für optische Zwecke. (Jan.)	'Zeitschr. f. Instrumentenkunde,' x. 1–6; 'Beiblätter,' xiv. 274–275 (Abs.)
H. W. Vogel . .	Ueber Farbenwahrnehmungen. (Read Jan. 10.)	'Verh. phys. Ges. Berlin,' ix. 1–8; 'Beiblätter,' xiv. 629 (Abs.)
E. Doumer . .	Sur les pouvoirs réfringents moléculaires des sels en dissolution. (Read Jan. 6, Jan. 20, May 5.)	'C. R.' cx. 40–42, 139–141, 957–958; 'Nature,' xli. 263, xlii. 72 (Abs.); 'Beiblätter,' xiv. 767–768 (Abs.); 'Chem. News,' lxi. 49 (Abs.); 'J. Chem. Soc.' lviii. 433–1033 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 374 (Abs.)
J. L. Soret and A. A. Rilliet.	Sur l'absorption des rayons ultraviolets par quelques substances organiques faisant partie de la série grasse. (Read Jan. 20.)	'C. R.' cx. 137–139; 'Zeitschr. f. physikal. Chem.' v. 275 (Abs.)
P. Barbier and L. Roux.	Recherches sur la dispersion dans les composés aromatiques. (Feb.)	'Bull. soc. chim.' [3], iii. 255; 'Chem. News,' lxiii. 11 (Abs.)
C. A. Bischoff and P. Walden.	Ueber die physikalischen Constanten der substituirten Aethenyltricarbonsäureëster. (Recd. Feb. 27. Read March 10.)	'Ber.' xxiii. 660–664; 'J. Chem. Soc.' lviii. 745–746 (Abs.)
P. Barbier and L. Roux.	Recherches sur la dispersion des dissolutions aqueuses. (Read March 3, March 10, May 27.)	'C. R.' cx. 457–460, 527–532, 1071–1074; 'J. Chem. Soc.' lviii. 673–674 (Abs.); 'Nature,' xli. 455, 479 (Abs.); 'Beiblätter,' xiv. 368, 502 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 84 (Abs.)

PHYSICAL RELATIONS, 1890.

B. Walter . .	Sur les indices de réfraction des solutions salines. (Read March 11.)	'C. R.' cx. 708–709; 'Chem. News,' lxi. 192 (Abs.); 'Beiblätter,' xiv. 505 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 86 (Abs.)
R. Nasini . .	Sulla dispersione dei composti organici. (Read March 16.)	'Rend. d. R. Accad. Lincei,' vi. 1st sem. 211–215; 'Gazz. chim. ital.' xx. 356–361.
J. F. Eykman .	Ueber die Umwandlung von Allyl in Propenylbenzolderivate, ihre Dispersion und Refraction. (Recd. March 17. Read March 24.)	'Ber.' xxiii. 855–864; 'J. Chem. Soc.' lviii. 748–749 (Abs.); 'Beiblätter,' xiv. 502–505 (Abs.)
F. W. Semmler .	Ueber indisches Geraniumöl. (Recd. April 10. Read April 28.)	'Ber.' xxiii. 1098–1103.
F. Schütt . .	Ueber die Bestimmung der Molecularrefraction fester chemische Verbindungen in Lösungen derselben. (Read April 29.)	'Zeitschr. f. physikal. Chem.' v. 349–373; 'J. Chem. Soc.' lviii. 1033–1034 (Abs.); 'Beiblätter,' xiv. 772–774 (Abs.)
T. Costa . .	Sul peso moleculare e sul potere rifrangente del bicloruro di zolfo. (Read May 4.)	'Rend. d. R. Accad. d. Lincei' [4], vi. 408–411; 'Zeitschr. f. physikal. Chem.' vi. 286 (Abs.); 'Gazz. chim. ital.' xx. 367–372.
C. Schall and C. Dralle.	Studien über das Brazilin. IV. (Read May 19.)	'Ber.' xxiii. 1428–1437.
P. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques (alcoöls de la série grasse). (Read May 27.)	'C. R.' cx. 1071–1074; 'Nature,' xlii. 143 (Abs.); 'Chem. News,' lxi. 289 (Abs.); 'J. Chem. Soc.' lviii. 1034–1035 (Abs.)
A. Schrauf . .	Ueber die thermische Veränderung der Brechungsexponenten des prismatischen Schwefels. (Read May 8.)	'Anzeiger d. K. Akad. Wien,' xxvi. 105–106; 'Beiblätter,' xv. 37–38.
P. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques (éthers oxydes). (Read July 21.)	'C. R.' cxi. 180–183; 'Chem. News,' lxii. 74 (Abs.)
„ .	Recherches sur la dispersion dans les composés organiques (acides gras). (Read July 28.)	'C. R.' cxi. 235, 236; 'Nature,' xlii. 360 (Abs.); 'Chem. News,' lxii. 85 (Abs.)
R. Loewenherz .	Ueber die Molecularrefraction der Nitrate. (Read July 14.)	'Ber.' xxiii. 2180–2182.
H. E. J. G. du Bois and H. Rubens.	Brechung und Dispersion des Lichtes in einigen Metallen. (Read July 24.)	'Sitzungsb. Akad. Berl.' 1890, 955–968; 'Phil. Mag.' [5], xxx. 365–378 (Abs.)
S. P. Langley and F. W. Very.	On the Cheapest Form of Light; from Studies at the Alleghany Observatory. (Aug.)	'Amer. J. Sci.' [3], xl. 97–113; 'Nature,' xlii. 482 (Abs.)

J. J. Kanonnikoff .	Ueber die Wechselbeziehungen zwischen den Drehungs- und Brechungsvermögen chemischer Verbindungen. (Aug.)	'J. Russ. Phys.-Chem. Soc.' 1890, 85–86; 'Zeitschr. f. physikal. Chem.' vi. 87 (Abs.)
W. Marshall Watts	A New Series of Wave-length Tables of the Spectra of the Elements and Compounds. (Report of the Committee.) (Sept.)	'Brit. Assoc. Rep.' 1890, 224–261.
S. P. Thompson .	On the Use of Fluor Spar in Optical Instruments. (Sept.)	'Phil. Mag.' [5], xxxi. 120–123.
T. Pelham Dale .	On certain Relations existing among the Refractive Indices of the Chemical Elements. (Nov.)	'Chem News,' lxii. 259 (Abs.); 'Nature,' xliii. 118 (Abs.)
V. Schumann .	Photographische Gesammtaufnahme des Spectrums zwischen den Wellenlängen 160 und 200 $\mu\mu$.	'Eder's Jahrb. d. Photog.' iv. 158–163; 'Beiblätter,' xiv. 615–616 (Abs.)
L. Buchkremer .	Ueber die beim Mischen von zwei Flüssigkeiten stattfindenden Volumänderung und deren Einfluss auf das Brechungsvermögen. (Inaug.-Diss. Bonn, 1890, 46 pp.)	'Beiblätter,' xiv. 768–769 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 161–186 (Abs.)
C. Pulfrich . .	Das Totalreflectometer und das Refractometer für Chemiker, ihre Anwendung in der Krystalloptik und zur Untersuchung der Lichtbrechung von Flüssigkeiten. (Leipzig: W. Engelmann, 1890.)	'Nature,' xliv. 538 (notice)
Ph. Barbier and L. Roux.	Recherches sur la dispersion dans les composés aromatiques.	'Bull. soc. chim. franç.' [3], iii. 255–261; 'Beiblätter,' xiv. 500–502 (Abs.)

1891.

J. W. Brühl . .	Ueber die Messung der Brechungsexponenten bei höheren Temperaturen mittelst des Totalreflectometer. (Read Jan. 26.)	'Ber.' xxiv. 286–299; 'Zeitschr. f. physikal. Chem.' vii. 429 (Abs.)
G. Lippmann . .	Sur la photographie des couleurs (première note). (Read Feb. 2.)	'C. R.' cxii. 274–275; 'Chem. News,' lxiii. 87–88.
G. D. Liveing and J. Dewar.	On the Influence of Pressure on the Spectra of Flames. (Read Feb. 19.)	'Proc. Roy. Soc.' xlix. 217–227; 'Chem. News,' lxiii. 143–145, 155–156 (Abs.); 'Zeitschr.' f. physikal. Chem.' viii. 332 (Abs.)
G. Higgs . . .	On the Bisulphite Compounds of Alizarin Blue and Cærulin as Sensitisers for Rays of Low Refrangibility. (Recd. Feb. 19. Read March 12.)	'Proc. Roy. Soc.' xlix. 345–346; 'Chem. News,' lxiii. 157.
W. Cassie . .	On the Effect of Temperature upon the Refractive Index of certain Liquids. (Recd. Feb. 19. Read March 12.)	'Proc. Roy. Soc.' xlix. 343–345.

PHYSICAL RELATIONS, 1891.

W. de W. Abney .	The Numerical Registration of Colour. Preliminary Notice. (Recd. Feb. 6. Read Feb. 19.)	'Proc. Roy. Soc.' xlix. 227–233.
H. A. Rowland .	Report of Progress in Spectrum Work. (Feb.)	'Johns Hopkins Univ. Circ.' x. No. 25, 41–42; 'Chem. News,' lxiii. 133–134.
Ph. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques (éthers). (Read March 16.)	'C. R.' cxii. 582–584; 'Chem. News,' lxiii. 166 (Abs.)
J. H. Gladstone .	Molecular Refraction and Dispersion of various Substances. (Read March 19.)	'J. Chem. Soc.' lix. 290–301; 'Proc. Chem. Soc.' 1891, 35–36 (Abs.); 'Chem. News,' lxiii. 173–174 (Abs.); 'Nature,' xliii. 549–550 (Abs.); 'Zeitschr. f. physikal. Chem.' viii. 335 (Abs.)
A. Crova . .	Sur la mesure optique des hautes températures. (Read April 19.)	'C. R.' cxiv. 941–943; 'Beiblätter,' xvii. 316 (Abs.)
F. L. Perrot . .	Recherches sur la réfraction et la dispersion dans une série isomorphe de cristaux à deux axes. (Read April 27.)	'C. R.' cxi. 967–969; 'Zeitschr. f. physikal. Chem.' vii. 335 (Abs.)
A. A. Michelson .	On the Application of Interference Methods to Spectroscopic Measurements. (April.)	'Phil.Mag.' [5], xxxi. 359–363.
W. de W. Abney .	On the Examination for Colour of Cases of Tobacco Scotoma, and of Abnormal Colour Blindness. (Recd. April 29. Read May 14.)	'Proc. Roy. Soc.' xlix. 491–508.
"	On the Limit of Visibility of the Different Rays of the Spectrum. (Read May 14.)	'Proc. Roy. Soc.' xlix. 509–518; 'Beiblätter,' xvi. 741 (Abs.)
H G. Ellinger .	Der Concentrationsgrad von Lösungen, bestimmt durch das Brechungsvermögen. (May.)	'J. prakt. Chem.' xliv. 152–157; 'Chem. News,' lxiv. 262 (Abs.)
A. Johnson . .	Newton's Use of Slit and Lens in forming a Pure Spectrum. (Read May 27.)	'Proc. and Trans. Roy. Soc. Canada,' ix. Sect. III. 45–54; 'Beiblätter,' xvii. 825 (Abs.)
G. Kümmell . .	Rotationsdispersion weinsaürer Salze. (June.)	'Ann. Phys. u. Chem.' [N.F.], xliii. 509–515; 'Zeitschr. f. physikal. Chem.' viii. 569 (Abs.)
W. H. Perkin. .	The Refractive Power of certain Organic Compounds at Different Temperatures. (Read June 18.)	'J. Chem. Soc.' lxi. 287–310; 'Proc. Chem. Soc.' 1891, 115–117 (Abs.); 'Chem. News,' lxiv. 19–20 (Abs.); 'Zeitschr. f. physikal. Chem.' viii. 692 (Abs.); 'Beiblätter,' xvii. 559–561 (Abs.)

J. H. Gladstone	The Molecular Refraction and Dispersion of various Substances. (Read June 4.)	'J. Chem. Soc.' lix. 589–598; 'Chem. News,' lxiii. 304–305(Abs.); 'Zeitschr. f. physikal. Chem.' ix. 223–225 (Abs.)
M. Labatut	Sur l'absorption et la photographie des couleurs. (Read July 20.)	'C. R.' cxiii. 126–129; 'Beiblätter,' xvi. 364–365 (Abs.)
J. H. Gladstone and W. Hibbert.	Experiments on the Molecular Refraction of Electrolytes in Solution. (Read Aug. 26.)	'Brit. Assoc. Rep.' 1891, 609; 'Beiblätter,' xvi. 605 (Abs.)
A. Jonas	Orthochromatische Bromsilber-Collodionemulsion. (Aug.)	'Phot. Mittheil.' xxviii. 155–157, 172–174; 'Beiblätter,' xvi. 538 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of Liquid Oxygen, and on the Refractive Indices of Liquid Oxygen, Nitrous Oxide, and Ethylene. (Aug.)	'Phil. Mag.' [5], xxxiv. 205–209; 'Zeitschr. f. physikal. Chem.' x. 430 (Abs.)
F. Aymonnet	Relation entre l'indice de réfraction d'un corps, sa densité, son poids moléculaire et son pouvoir diathermane. (Read Sept. 21.)	'C. R.' cxiii. 418–421; 'Beiblätter,' xvi. 430 (Abs.)
H. Rubens	Ueber eine Methode zur Bestimmung der Dispersion ultra-rothen Strahlen. (Oct.)	'Verhandl. der phys. Gesellsch. Berl.' 1891, 83–84; 'Nature,' xlv. 48 (Abs.)
C. B. Thring	Colour Photography by Lippmann's Process. (Nov.)	'Amer. J. Sci.' [3], xlii. 388–390; 'Beiblätter,' xvi. 364 (Abs.)
W. de W. Abney	Colour Photometry. (Read Nov. 19.)	'Proc. Chem. Soc.' 1891, 150–154 (Abs.); 'Chem. News,' lxiv. 295–296 (Abs.)
E. L. Nicholls and B. W. Snow.	On the Influence of Temperature on the Colour of Pigments. (Nov.)	'Phil. Mag.' [5], xxxii. 401–424; 'Zeitschr. f. physikal. Chem.' ix. 380 (Abs.); 'Beiblätter,' xvi. 361–363 (Abs.)
T. P. Dale	On certain Relations existing amongst the Refractive Indices of the Chemical Elements. (Phys. Soc. Read Nov. 14.)	'Chem. News,' lxii. 259 (Abs.); 'Beiblätter,' xvi. 274 (Abs.)
A. König	Ueber den Helligkeitswerth der Spectralfarben bei verschiedener absoluter Intensität. (Hamburg, 1891, 84 pp.)	'Zeitschr. f. Psychol. u. Physiol. d. Sinnesorgane,' iv. 422–424 (Abs.); 'Beiblätter,' xvii. 659–660 (Abs.)

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C. E. Guillaume	L'énergie dans le spectre. (Jan.)	'Revue Générale des Sciences,' iii. 12–21.
A. König and R. Ritter.	Ueber den Helligkeitswerth der Spectralfarben bei verschiedener absoluter Intensität. (Read Jan. 29.)	'Ann. Phys. u. Chem.' [N.F.], xlv. 604–607; 'Phil. Mag.' [5], xxxiii. 541–542.

PHYSICAL RELATIONS, 1892.

J. Chappuis . .	Réfraction des gaz liquéfiés. (Read Feb. 8.)	'C. R.' cxiv. 286–288; 'Beiblätter,' xvi. 425 (Abs.)
C. E. Guillaume .	Les constantes radiométriques. (Feb.)	'Rev. Générale des Sciences,' iii. 93–94.
P. Bary . . .	Sur les indices de réfraction des solutions salines. (Read Feb. 8.)	'C. R.' cxiv. 827–831; 'Beiblätter,' xvi. 735 (Abs.); 'J. Chem. Soc.' lxii. 929 (Abs.)
A. Weigle . .	Spectrophotometrische Untersuchungen der Salze aromatischer Basen. (Feb.)	'Zeitschr. f. physikal. Chem.' xi. 227–247, 426–428: 'Beiblätter,' xvii. 506 (Abs.)
E. Brodhun . .	Ueber die Empfindlichkeit des grünblinden und des normalen Auges gegen Farbenänderung im Spectrum. (July.)	'Zeitschr. f. Psychol. u. Physiol. der Sinnesorgane,' iii. 97–107.
J. Elster and H. Geitel.	Beobachtungen des atmosphärischen Potentialgefälles und der ultravioletten Sonnenstrahlung. (Read March 10.)	'Sitzungsb. Akad. Wien,' ci. II.*a*, 703–856.
F. Aymonnet .	Des *maxima* calorifiques périodiques observés dans les spectres du flint, du crown et du sel gemme. (Read March 14.)	'C. R.' cxiv. 582–585; 'Beiblätter,' xvii. 336–337 (Abs.)
F. Maclean . .	Photographies spectrales obtenues avec un réseau de Rowland. (Read April 1.)	'J. Soc. Franç. de Phys.' 1892, 165–166.
G. Lippmann . .	Sur la photographie des couleurs (deuxième note). (Read April 25.)	'C. R.' cxiv. 961–962; 'Beiblätter,' xvi. 611 (Abs.)
C. Pulfrich . .	Ueber den Einfluss der Temperatur auf die Lichtbrechung des Glases. (April.)	'Ann. Phys. u. Chem.' [N.F.], xlv. 609–655; 'Zeitschr. f. physikal. Chem.' ix. 770 (Abs.)
F. J. Rogers . .	Magnesium as a Source of Light. (April.)	'Amer. J. Sci.' [3], xliii. 301–314; 'Beiblätter,' xvi. 606–608 (Abs.)
F. Dussaud . .	Sur la réfraction et la dispersion du chlorate de soude cristallisé. (April.)	'Arch. de Genève' [3], xxvii. 380–381, 521–536; 'Beiblätter,' xvi. 611 (Abs.)
W. Baily . .	On the Construction of a Colour Map. (Phys. Soc. Read April 8.)	'Phil. Mag.' [5], xxxiii. 496–503.
F. Schütt . .	Ueber die Bestimmung der Molecularrefraction fester chemischer Verbindungen in Lösungen derselben. (April.)	'Zeitschr. f. physikal. Chem.' ix. 349–377.
R. Bach . . .	Thermochemie des Hydrazins, nebst einer Bemerkung über die Molecularrefraction einiger Stickstoffverbindungen. (April.)	'Zeitschr. f. physikal. Chem.' ix. 241–263; 'Beiblätter,' xvi. 515–517 (Abs.)
Committee . .	Report on Colour-Vision. (April 28.)	'Proc. Roy. Soc.' li. 281–396.

PHYSICAL RELATIONS, 1892.

H. F. Newall	On a Diagram useful as a Guide in adjusting a Diffraction-grating Spectroscope. (May.)	'Monthly Not. R.A.S.' lii. 510–512; 'Beiblätter, xvii. 129–130 (Abs.)
D. Shea	Zur Brechung und Dispersion des Lichtes durch Metallprismen. (July.)	'Ann. Phys. u. Chem.' [N.F.], xlvii. 178–202; 'Nature,' xlvii. 68–69 (Abs.)
H. Landolt and H. Jahn.	Ueber die Molecularrefraction einiger einfachen organischen Verbindungen für Strahlen von unendlichgrosser Wellenlänge. (July.)	'Sitzungsb. Akad. Berl.' 1892, II. 729–754; 'Zeitschr. f. physikal. Chem.' ix. 289–320.
A. A. Michelson	On the Application of Interference Methods to Spectroscopic Measurements. (Read Aug. 6.)	'Brit. Assoc. Rep.' 1892, 170–185; 'Nature,' xlvi. 385 (Abs.); 'Phil. Mag.' [5], xxxiv. 280–299.
F. Zecchini	Rifrazione atomiche degli elementi rispetto della luce gialla del sodio. (Read Aug. 20.)	'Gazz. chim. ital.' xxii. II. 592–604; 'J. Chem. Soc.' lxiv. II. 253–254 (Abs.)
G. D. Liveing and J. Dewar.	On the Spectrum of Liquid Oxygen, and on the Refractive Indices of Liquid Oxygen, Nitrous Oxide, and Ethylene. (Aug.)	'Phil. Mag.' [5], xxxiv. 205–209; 'Physikal. Revue,' ii. 288–294; 'J. Chem. Soc.' lxiv. II. 201–202 (Abs.); 'Beiblätter,' xvii. 121–122 (Abs.)
H. Rubens and B. W. Snow.	Ueber die Brechung der Strahlen von grosser Wellenlänge in Steinsalz, Sylvin und Fluorite. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], xlvi. 529–541; 'Nature,' xlvi. 483 (Abs.)
J. M. Eder	Ueber die Verwendbarkeit der Farbenspectren verschiedener Metalle zur Bestimmung der Wellenlänge im Ultravioletten, mit Bezug auf des Spectrums, des Sonnenlichtes, Drummond'schen Magnesium- und electrischen Bogenlichtes. (Aug.)	'Denkschr. Akad. Wien' (1892), lx. 264–265; 'Beiblätter,' xvii. 331–332 (Abs.)
W. Marshall Watts	On Wave-Length Tables of the Spectra of the Elements and Compounds. (Read Aug. 5.)	'Brit. Assoc. Rep.' 1892, 193–260.
C. Piazzi Smith	Researches on the Ultra-Violet Rays of the Solar Spectrum. (Read Aug. 5.)	'Brit. Assoc. Rep.' 1892, 74–76.
J. Kerr	On Dispersion in Double Refraction due to Electrical Stress. (Aug.)	'Brit. Assoc. Rep.' 1892, 157–158; 'Beiblätter,' xvii. 768–769 (Abs.)
H. Landolt and Hans Jahn.	Ueber die Molecularrefraction einiger einfachen organischen Verbindungen für Wellen von unendlich grosser Wellenlänge. (Sept.)	'Zeitschr. f. physikal. Chem.' x. 289–320; 'Beiblätter,' xvii. 329–331 (Abs.)
M. Le Blanc	Eine einfache Methode zur Bestimmung von Brechungsexponenten optisch-isotroper Körper. (Oct.)	'Zeitschr. f. physikal. Chem.' ix. 433–449; 'Beiblätter,' xvii. 441–442 (Abs.)

PHYSICAL RELATIONS, 1892.

G. Lippmann . .	Photographies colorées du spectre sur albumine et sur gélatine bichromatées. (Read Oct. 24.)	'C. R.' cxv. 575; 'Ber.' xxv. (Ref.), 850 (Abs.); 'Beiblätter,' xvii. 933 (Abs.); 'Nature,' xlvii. 23 (Abs.)
J. F. Eykman .	Recherches réfractométriques. (Read Oct. 5 and 10.)	'Recueil des trav. chim. des Pays-Bas,' xii. 157–197, 268–286; 'Beiblätter,' xvii. 1048–1049, xviii. 452–453 (Abs.); 'Ber. xxv. 3069–3079, xxvii. (Ref.), 11 (Abs.); 'J. Chem Soc.' lxiv. II. 1-2 (Abs.)
B. Hasselberg .	Projet d'une méthode pour déterminer avec grande exactitude l'indice de réfraction et la dispersion de l'air. (Read Nov. 9.)	'Oefversigt af K. Vet. Akad. Förh. (Stockholm) (1892), xlix. 441–449; 'Beiblätter,' xvii. 915 (Abs.)
G. Meslin . .	Sur la photographie des couleurs ('Physikal. Revue,' ii. 681–701). (Nov.)	'Ann. chim. et phys.' [6], xxvii. 369–392; 'Beiblätter,' xviii. 342 (Abs.)
W. H. Perkin .	On the Refractive Power of certain Organic Substances at Different Temperatures. (Nov.)	'J. Chem. Soc.' lxi. 287–310; 'Zeitschr. f. physikal. Chem.' x. 667 (Abs.)
F. L. Perrot . .	Nouvelles recherches sur réfraction et dispersion dans une série isomorphe des cristaux à deux axes (sulfates doubles à $6H_2O$). (Read Dec. 1.)	'Arch. de Genève' [3], xxix. 28–50, 121–140; 'Arch. néerland.' xxix. 121–141.
F. Zecchini . .	Sul potere rifrangente del fosforo. Potere rifrangente degli acidi del fosforo, et dei loro sali sodici. (Read Dec. 6.)	'Gazz. chim. ital.' xxiii. I. 109–120; 'J. Chem. Soc.' lxiv. II. 254 (Abs.)
W. B. Croft . .	The Spectra of the Colours in various Orders of Colours of Newton's Scale. (Read Dec. 9.)	'Chem. News,' lxvi. 300–301 (Abs.); 'Nature,' xlvii. 190 (Abs.); 'Beiblätter,' xvii. 1072 (Abs.)
C. Féry . . .	Sur l'étude des réactions chimiques dans une masse liquide par l'indice de réfraction. (Read Dec. 26.)	'C. R.' cxv. 1309–1312; 'J. Chem. Soc.' lxiv. II. 201 (Abs.)
A. Sella . . .	Sulla variazione dell' indice di rifrazione del diamante colla temperatura e su di una generalizzazione del metodo di mimina deviazione col prisma.	'Rend. R. Accad. d Lincei,' vii. (2nd sem.), 300–308; 'Beiblätter,' xvi. 423–424 (Abs.)
W. Hallwachs .	Ueber das Brechungsexponenten verdünnter Lösungen.	'Ann. Phys. u. Chem.' [N.F.], xlvii. 380–388.
A. Kurz . . .	Die kleinste Ablenkung im Prisma.	'Zeitschr. f. Math. u. Phys.' (Leipzig), xxxvii. 317–318.
E. Mach . .	Ueber eine elementare Darstellung der Fraunhofer'schen Beugungserscheinung, ins besondere der Gitterspectra.	'Zeitschr. f. phys. u. chem. Unterricht,' v. 225–229.

B. Krone	Einige Erfahrungsnotizen über farbige Photographie von Spectren.	'Phot. Mittheil.' xxix. 67–70.

1893.

E. Carvallo	Perfectionnements à la méthode de M. Mouton pour l'étude du spectre calorifique. (Jan.)	'J. de phys.' [3], ii. 27–36; 'Beiblätter,' xvii. 562–563 (Abs.)
W. Grosse	Ueber die Länge der Spectren und Spectralbezirke. (Jan.)	'Zeitschr. f. Instrumentenkunde,' xiii. 6–13.
W. Pole	On the Present State of Knowledge and Opinion with regard to Colour-Blindness. (Read Jan. 16.)	'Trans. Roy. Soc. Edinb.' xxxvii. 441–479; 'Nature,' xlvii. 335 (Abs.)
J. H. Gladstone	Note on some Recent Determinations of Molecular Refraction and Dispersion. (Read Feb. 10.)	'Phil. Mag.' [5], xxxv. 204–210; 'J. Chem. Soc.' lxiv. II. 254 (Abs.); 'Beiblätter,' xvii. 647–648 (Abs.)
W. H. Perkin	The Magnetic Rotation and Refractive Power of Ethylene Oxide. (Read March 2.)	'J. Chem. Soc.' lxiii. 488–492; 'Ber.' xxvi. (Ref.), 497 (Abs.); 'Beiblätter,' xvii. 959 (Abs.)
R. Nasini	Sul potere rifrangente per un raggio di lunghezza d' onda infinita. (Read March 8.)	'Gazz. chim. ital.' xxiii. I. 347–354.
A. Crova	Sur les bandes d'interférence des spectres des réseaux sur gélatine. (Read March 27.)	'C. R.' cxvi. 672–674; 'Beiblätter,' xviii. 193–194 (Abs.)
J. R. Rydberg	On a certain Asymmetry in Professor Rowland's Concave Gratings. (March.)	'Phil. Mag.' [5], xxxv. 190–199; 'Beiblätter,' xvii. 840 (Abs.)
A. Ghira	Sulla rifrazione atomica del Boro. (Read April 9.)	'Rend. R. Accad. Roma' [5], ii. 1st sem. 312–319.
S. Bloch	Sur la dispersion anomale. (Read April 10.)	'C. R.' cxvi. 746–748; 'Beiblätter,' xvii. 1046 (Abs.)
G. Lippmann	Photographies en couleurs exécutées d'après les méthodes interférentielles. (Read April 17.)	'C. R.' cxvi. 784.
A. A. Michelson	Comparaison du mètre international avec la longueur d'onde de la lumière du cadmium. (Read April 17.)	'C. R.' cxvi. 790–794.
T. Liebisch	Ueber die Spectralanalyse der Interferenzfarben optisch zweiaxiger Krystalle. (April.)	'Göttingen. Nachr.' 1893, 265–266.
H. Bouasse	Réflexion et réfraction dans les milieux isotropes transparents et absorbents. (April.)	'Ann. Chim. et Phys.' [6], xxviii. 433–498.
E. Hering	Ueber den Einfluss der *Macula lutea* auf Spectralfarbengleichungen. (May.)	'Arch. f. d. ges. Physiol.' liv. 277–312; 'Beiblätter,' xviii. 113–114 (Abs.)

W. de W. Abney .	On the Colours of Sky-Light, Sunlight, Cloud-Light, and Candle-Light. (Read June 1.)	'Proc. Roy. Soc.' liv. 2–4; 'Nature,' xlviii. 333–334 (Abs.)
F. Zecchini . .	Sopra un notevole caso di accrescimento anomalo nel potere rifrangente delle basi feniliche. (Read June 2.)	'Gazz. chim. ital.' xxiii. II. 42–47; 'J. Chem. Soc.' lxvi. III. 2 (Abs.)
A. Charpentier .	Sur le retard dans la perception des divers rayons spectraux. (Read June 13.)	'C. R.' cxvi. 1423-1426; 'Beiblätter,' xvii. 657 (Abs.)
A. Cornu . .	Sur divers méthodes relatives à l'observation des propriétés appelées anomalies focales des réseaux diffringents. (Read June 19.)	'C. R.' cxvi. 1421-1428; 'Beiblätter,' xviii. 196–198 (Abs.)
H. A. Rowland .	A New Table of Standard Wave-Lengths. (July.)	'Phil. Mag.' [5], xxxvi. 49–75.
K. Zimányi . .	Die Hauptbrechungsexponenten der wichtigeren gesteinbildenden Mineralien bei Na-licht. (July.)	'Zeitschr. f. Kryst. u. Min.' xxii. 321–359.
C. Pulfrich . .	Ueber Dispersionsbestimmung nach der Totalreflexionsmethode mittelst micrometrischer Messung. (July.)	'Zeitschr. f. Instrumentenkunde,' xiii. 267–273; 'Beiblätter,' xviii. 77 (Abs.)
F. Aymonnet . .	Sur les *maxima* périodiques des spectres. (Read Aug. 2, Sept. 18.)	'C. R.' cxvii. 304–306, 402–405; 'Beiblätter,' xvii. 1057–1058 (Abs.)
G. D. Liveing and J. Dewar.	On the Refractive Indices of Liquid Nitrogen and Air. (Oct.)	'Phil. Mag.' [5], xxxvi. 328–331; 'Beiblätter,' xviii. 334 (Abs.); 'J. Chem. Soc.' lxvi. II. 37 (Abs.)
S. Bloch . .	Mesure du pouvoir absorbant pour la lumière de lames minces possédant la réflexion métallique. (Read Nov. 13.)	'C. R.' cxvii. 661–663; 'Beiblätter,' xviii. 338–339 (Abs.)
H. M. Ward . .	The Action of Light on Bacteria. Part III. (Read Dec. 14.)	'Proc. Roy. Soc.' liv. 472–475 (Abs.)

1894.

J. Kanonnikoff .	Ueber die Beziehungen zwischen dem Lightbrechungs- und Drehungsvermögen chemischer Verbindungen, und über eine neue Bestimmungsmethode der specifische Drehung optisch activer Stoffe. (Feb.)	'J. prakt. Chem.' [N.F.], xlix. 137–184; 'Ber.' xxvii. (Ref.), 247-248 (Abs.)

V.

FLUORESCENCE.

1880.

J. W. Draper . .	On the Phosphorograph of a Solar Spectrum, and on the Lines in its Infra-red Region. (Dec.)	'Proc. Amer. Acad.' [N.S.], viii. 223–234.

FLUORESCENCE, 1880, 1881, 1882, 1886, 1888, 1889, 1890, 1891.

F. S. Provenzali .	Sulla fosforescenza e fluorescenza. (Read Dec. 19.)	'Atti dell' Accad. Pontif. de' Nuovi Lincei,' xxxiv. 1–8; 'Riv.Sci.Industriale,' xiii. 374–384.

1881.

E. Dreher . .	Die Ursache der Phosphorescenz der sogenannten 'Leuchtenden Materie' nach vorangegangener Insolation. ('Die Natur,' xxx. 4 pp.)	'Beiblätter,' vi. 685 (Abs.)

1882.

H. W. Vogel . .	Ueber die Benutzung der Phosphorescenzplatten für Empfindlichkeitsbestimmungen. (May.)	'Phot. Mitth.' xix. 46–47; 'Beiblätter,' vi. 876 (Abs.)

1886.

E. Lommel . .	Phosphorescenz. (Read Nov. 6.)	'Sitzungsb. Akad. Bayer. xvi. 283–298; 'Ann. Phys. u. Chem.' [N.F.], xxx. 473–487; 'J. Chem. Soc.' lii. 410–411 (Abs.)

1888.

M. Wolf and P. Lenard.	Phosphorescenz und Photographie. (Aug.)	'Eder's Jahrb. f. Photog.' 1889, 141–148; 'Beiblätter,' xiii. 221 (Abs.)

1889.

B. Walter . .	Die Aenderung des Fluorescenzvermögen mit der Concentration. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], xxxvi. 502–518; 'Zeitschr. f. physikal. Chem.' iii. 234 (Abs.)
„ . .	Ueber den Nachweis des Zerfalles von Moleculargruppen in Lösungen durch Fluorescenz- und Absorptionserscheinung. (Jan.)	'Ann. Phys. u. Chem.' [N.F.], xxxvi. 518–532; 'Zeitschr. f. physikal. Chem.' iii. 234 (Abs.)
V. Klatt and P. Lenard.	Ueber die Phosphorescenzen des Kupfers, Bismuths und Mangans in den Erdalkalisulphiden. (July.)	'Ann. Phys. u. Chem.' [N.F.], xxxviii. 90–107, 'J. Chem. Soc.' lviii. 201 (Abs.)

1890.

L. de Boisbaudran.	Sur quelques nouvelles fluorescences. (Read Jan. 6.)	'C. R.' cx. 24–28; 'Nature,' xli. 263 (Abs.)
E. Lommel . .	Phosphorophotographie des ultrarothen Gitterspectrums. (Read March 1.)	'Sitzungsb. d. Akad. München,' xx. 83–87.
E. E. Brooks . .	On the Phosphorescence of Lithium Compounds *in vacuo* and the Spectra of Coated Terminals. (Nov.)	'Chem. News,' lxii. 239.

1891.

H. Becquerel . .	Sur les différentes manifestations de la phosphorescence des minéraux sous l'influence de la lumière et de la chaleur. (Read Mar. 16.)	'C. R.' cxii. 557–563; 'Nature,' xliii. 504 (Abs.); 'Chem. News,' lxiii. 165–166 (Abs.)

W. Böhlendorf .	Bemerkung zu der Abhandlung des Herrn B. Walter 'Ueber den Nachweis des Zerfalles von Moleculargruppen in Lösungen durch Fluorescenz und Absorptionserscheinungen.' (July.)	'Ann. Phys. u. Chem.' [N.F.], xliii. 784-789.
P. Drude and W. Nernst.	Ueber die Fluorescenzwirkung stehender Lichtwellen. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xlv. 460-474.

1892.

G. Salet . .	Sur la loi de Stokes: sa vérification et son interprétation. (Read Aug. 1.)	'C. R.' cxv. 283-284; 'Beiblätter,' xvi. 741 (Abs.); 'Nature,' xlvi. 364 (Abs.)
W. N. Hartley .	Observations on the Origin of Colour and on Flurorescence. (Read Dec. 1.)	'J. Chem. Soc.' lxiii. 253-256; 'Proc. Chem. Soc.' No. 116, 188-189 (Abs.)

VI.

ASTRONOMICAL APPLICATIONS.

1880.

C. S. Hastings .	A Theory of the Constitution of the Sun, founded upon Spectroscopic Observations, original and other. (Presented Oct. 13.)	'Proc. Amer. Acad.' [N.S.], viii. 140-152.

1882.

H. Draper . .	On Photographs of the Spectra of the Nebula in Orion. (April.)	'Amer. J. Sci.' [3], xxiii. 339-341; 'Nature,' xxvi. 83-34; 'J. de Phys.' [2], ii. 49-50 (Abs.)
C. Fiévez . .	La Grande Comète du Sud.	'Ann. Observ. Bruxelles,' 1883, 201-208.
C. C. Krafft . .	Spectroscopic Researches at the Norwegian Polar Station at Bossekop. (Report, 1882, Part II.)	'Nature,' xxxix. 515-516; (Abs.); 'Beiblätter,' xiii. 884-885 (Abs.)

1883.

C. Piazzi Smyth .	Note on Sir David Brewster's Line Y in the Infra-Red of the Solar Spectrum. (Read Dec. 17.)	'Trans. Roy. Soc. Edinb.' xxxii. 233-238; 'Beiblätter,' ix. 335 (Abs.)
C. Fiévez . .	Etude de la région rouge (A-C) du spectre solaire.	'Ann. Observ. Bruxelles,' v. 3-5; 'Beiblätter,' vii. 849 (Abs.)

1884.

N. C. Dunér . .	Sur les étoiles à spectres de la troisième classe. (Presented June 11.)	'Handlingar K. Svensk. Vet. Akad.' xxi. No. 2, 1-92; 'Beiblätter,' x. 736-737 (Abs.); 'Nature,' xxxii. 610 (Abs.); xxxiii. 583-585 (Abs.); xxxvii. 234-236, 260-262.

ASTRONOMICAL APPLICATIONS, 1884, 1885, 1886.

S. P. Langley, F. W. Very, and J. E. Keeler.	On the Temperature of the Surface of the Moon. (Read Oct. 17.)	'Mem. Nat. Acad. Sci.' (Washington), iii. 13–42; 'Nature,' xxxiii. 210 (Abs.), 211–212 (Abs.); 'Zeitschr. f. Instrumentenkunde,' vi. 358–361 (Abs.); 'Beiblätter,' x. 304–306 (Abs.)
E. von Gothard	Mittheilungen aus dem Astrophysikalischen Observatorium zu Herèny. ('Publicationen des Astrophys. Observ. zu Herèny in Ungarn,' 1884, 35–63). (Read Dec. 15.)	'Math. u. naturwiss. Ber. aus Ungarn,' iii. 34–39; 'Beiblätter,' x. 624 (Abs.)

1885.

L. Thollon	Nouveau dessin du spectre solaire. (Read Sept. 7.)	'C. R.' ci. 565–567; 'Nature,' xxxii. 519 (Abs.); 'Beiblätter,' ix. 790 (Abs.); 'Bull. Astron.' iii. 330–343; 'Beiblätter,' x. 700–701 (Abs.)
E. C. Pickering	Photographic Spectra of Stars. (Presented Dec. 3.)	'Report of Harvard Coll. Observ.' 1885, 1–13; 'Nature,' xxxiii. 376–377 (Abs.)
W. H. M. Christie	Spectroscopic and Photographic Observations made at the Royal Observatory, Greenwich.	'Greenwich Observ. Report,' 1885, xxxii. 104 pp.; 'Beiblätter,' xii. 194–195 (Abs.)

1886.

A. A. Rambaut	The Spectroscopic Method of Determining the Distance of a Double Star. (Roy. Irish Acad. May 24, 1886.)	'Nature,' xxxv. 206–207 (Abs.)
S. P. Langley	On the Solar and Lunar Spectrum. (Read Nov. 9.)	'Mem. Nat. Acad. Sci. Washington,' iv. 159–179; 'Nature,' xli. 450 (Abs.)
S. P. Langley, C. A. Young, and E. C. Pickering.	On Pritchard's Wedge Photometer. (Presented Nov. 10.)	'Ann. Harvard Coll. Observ.' xviii. 301–324; 'Beiblätter,' xii. 337 (Abs.)
W. H. M. Christie	Spectroscopic and Photographic Results.	'Greenwich Observ. Reports,' 1886, pp. i–xiv and 1–97; 'Nature,' xxxvi. 140 (Abs.)
E. L. Trouvelot	Sur les changements temporaires de réfrangibilité des raies du spectre de la chromosphère et des protubérances solaires (Jan.)	'Bull. Astron.' iii. 9–22; 'Beiblätter,' x. 573–574; (Abs.); 'Nature,' xxxiii. 498 (Abs.), 504 (Abs.)
A. Huninger	Protuberantiæ Solares (in Hungarian).	'Ber. Erzb. Haynald'schen Observ. zu Kalocsa in Ungarn,' 1886, I. 1–17; 'Nature,' xxxix. 352 (Abs.)

ASTRONOMICAL APPLICATIONS,

1887.

O. T. Sherman	Bright Lines in Stellar Spectra. (Jan.)	'Gould's Astron. Journ.' No. xlix. 32–35; 'Nature,' xxxv. 378 (Abs.)
C. C. Hutchins and E. L. Holden.	On the Existence of certain Elements, together with the Discovery of Platinum, in the Sun. (Presented March 9.)	'Proc. Amer. Acad. Sci.' [N.S.], xv. 14–19; 'Amer. J. Sci.' [3], xxxiv. 451–456; 'Phil. Mag.' [5], xxiv. 325–330; 'J. Chem. Soc.' lii. 1065–1066 (Abs.); 'Nature,' xxxvii. 368 (Abs.); 'Ber.' xxi. (Ref.), 79 (Abs.); 'Beiblätter,' xii. 473–475 (Abs.)
J. Trowbridge and C. C. Hutchins.	Oxygen in the Sun. (Presented March 9.)	'Proc. Am. Acad. Sci.' xxiii. 1–9; 'Amer. J. Sci.' [3], xxxiv. 263–270; 'Phil. Mag.' [5], xxiv. 302–310; 'Nature,' xxxvii. 47, 114 (Abs.); 'J. Chem. Soc.' lii. 1065 (Abs.); 'Beiblätter,' xii. 352–355 (Abs.)
,,	On the Existence of Carbon in the Sun. (Presented March 9.)	'Proc. Amer. Acad. Sci.' xxiii. 10–13; 'Amer. J. Sci.' [3], xxxiv. 345–348; 'Nature,' xxxvii. 162 (Abs.); 'J. Chem. Soc.' lii. 1065 (Abs.); 'Ber.' xxi. (Ref.), 1–2 (Abs.); 'Beiblätter,' xii. 355–356 (Abs.)
S. J. Perry	Reports of the Observations of the Total Solar Eclipse of August 29, 1886, made at the Island of Carriacou. (Recd. April 5. Read May 5.)	'Phil. Trans.' clxxx. A. 351–362; 'Proc. Roy. Soc.' xlii. 316–318 (Abs.)
H. Pellat	Renversement des raies spectrales. Méthode pour déterminer la température du soleil. (Read May 28.)	'Bull. Soc. Philom.' [7], xi. 155–160; 'Beiblätter,' xi. 705–706 (Abs.)
T. E. Espin	A Probable New Class of Variable Stars. (Nov.)	'Wolsingham Observ. Circ.' No. xviii; 'Nature,' xxxvii. 158 (Abs.)
E. C. Pickering	Henry Draper Memorial First Annual Report of the Photographic Study of Stellar Spectra Conducted at the Harvard Observatory.	'Harvard Coll. Observ.' 1887, 10 pp.; 'Beiblätter,' xi. 637–638 (Abs.)
T. E. Espin	Spectroscopic Observations with the 17¼-in. Equatorial.	'Publications of the Liverpool Astron. Soc.' No. I. (1887), 8–11 (continued in 'Astron. Nachr.' No. 2788).
W. H. M. Christie	Spectroscopic and Photographic Results.	'Greenwich Observ. Reports,' 1887, pp. i–xiv and 1–66; 'Nature,' xxxviii. 153–154 (Abs.)

ASTRONOMICAL APPLICATIONS, 1887, 1888.

H. C. Vogel	Ueber Sternspectra. (Review of N. C. Dunér's Paper 'Sur les étoiles à spectres de la troisième classe.' Stockholm, 1885.)	'Vierteljahresschrift d. Astron. Ges.' xxii. 50–59; 'Beiblätter,' xii. 104 (Abs.)
P. Ubaghs	Détermination de la direction et de la vitesse du transport du système solaire dans l'espace. (IIme partie.)	'Bull. Acad. Belg.' [13], xiii. 66–70 (Report of MM. Folie and Houzeau on the paper); 'Nature,' xxxvi. 45 (Abs.)

1888.

J. Janssen	Note sur l'éclipse totale de Lune du 28 janvier dernier. (Read Jan. 30.)	'C. R.' cvi. 325–327.
S. J. Perry	The Chromosphere in 1887. (Jan.)	'The Observatory,' Feb. 1888, 129–130; 'Nature,' xxxvii. 424 (Abs.)
H. C. Vogel	Ueber die Bestimmung der Bewegung von Sternen im Visionsradius durch spectrographische Beobachtung. (Read Feb. 23.)	'Sitzungsb. Akad. Berlin,' 1888, 397–401; 'Nature,' xxxvii. 616 (Abs.); 'Astron. Nachr.' No. 2839, 97–100.
H. Crew	On the Period of the Rotation of the Sun as determined by the Spectroscope. (Feb.)	'Amer. J. Sci.' [3], xxxv. 151–159; 'Nature,' xl. 550 (Abs.)
J. C. B. Burbank	Photography of the least Refrangible Portion of the Solar Spectrum. (Read March 14.)	'Proc. Amer. Acad. Sci.' [N.S.], xv. 301–304.
H. H. Turner	Report of the Observations of the Total Solar Eclipse of August 29, 1886, made at Grenville, in the Island of Grenada. (Recd. Feb. 23. Read March 15.)	'Phil. Trans.' clxxx. 385–398; 'Proc. Roy. Soc.' xliii. 428–430 (Abs.)
W. de W. Abney	Total Eclipse of the Sun observed on Caroline Island on May 6, 1883. (Recd. May 25. Read June 16, 1887. Revised June 4, 1888.)	'Phil. Trans.' clxxx. A. 119–135.
T. E. Espin	The Spectrum of R Cygni. ('Wolsingham Obs. Circ.' No. xxi.) (Aug.)	'Nature,' xxxviii. 423 (Abs.)
S. P. Langley	The Invisible Solar and Lunar Spectrum. (Dec.)	'Amer. J. Sci.' [3], xxxvi. 397–410; 'Phil. Mag.' [5], xxvi. 505–520; 'Nature,' xxxix. 189 (Abs.); 'Beiblätter,' xiii. 310–311 (Abs.); 'J. Chem. Soc.' lvi. 325 (Abs.)
E. von Gothard	Erfahrungen auf dem Gebiete der Himmels- und Spectral-Photographie.	'Eder's Jahrb. f. Photog.' 1888, 238–243.
J. Fènyi	Sonnen-Protuberanzen vom Jahre 1886.	'Ber. Erzb. Haynald'schen Obs. zu Kalocsa in Ungarn,' IV. 1–60; 'Nature,' xxxix. 352 (Abs.)
H. W. Vogel and N. C. Dunèr.	O'Gyalla Spectroscopic Catalogue.	'Nature,' xxxvii. 259 (Abs.)

ASTRONOMICAL APPLICATIONS, 1888, 1889.

E. C. Pickering .	The Henry Draper Memorial Second Annual Report of the Photographic Study of Stellar Spectra, conducted at Harvard College Observatory. (8 pp.)	'Beiblätter,' xii. 795–796 (Abs.); 'Nature,' xxxviii. 306–307 (extract).

1889.

A. Schuster . .	Observations of the Total Solar Eclipse of August 29, 1886. (Read Feb. 4.)	'Phil. Trans.' clxxx. 291–384; 'Nature,' xli. 327 (Abs.)
L. Darwin, A. Schuster, and E. W. Maunder.	On the Total Solar Eclipse of August 29, 1886. (Recd. Jan. 28. Read Feb. 14.)	'Phil. Trans.' clxxx. A. 291–350.
H. A. Rowland .	Photographic Map of the Solar Spectrum (second series). (Publication Agency of the Johns Hopkins University.) (Feb.)	'Chem. News,' lix. 124–125; 'Beiblätter,' xiii. 682 (Abs.)
H. C. Vogel . .	Ueber die auf den Potsdamen Observatorium unternommen Untersuchungen über die Bewegung der Sterne im Visionsradius vermittelst der spectrographischen Methode. (March.)	'Astr. Nachr.' cxxi. 241–258; 'Beiblätter,' xlii. 947–949 (Abs.) (compare 'Sitzungsb. Akad. Berl.' 1888, 397–401).
J. Waterhouse .	Photography of the Solar Spectrum. (March.)	'Phil. Mag.' [5], xxvii. 284.
" .	Photography of the Red End of the Spectrum. (Read April 3.)	'Proceedings of the Asiatic Soc. of Bengal,' 1889, No. 4, 154–158; 'Nature,' xli. 67 (Abs.)
W. Huggins . .	On the Limit of Solar and Stellar Light in the Ultra-Violet Part of the Spectrum. (Recd. March 28. Read April 4.)	'Proc. Roy. Soc.' xlvi. 133–135; 'Beiblätter,' xiii. 884 (Abs.)
T. E. Espin . .	The Spectra of R Leonis and R Hydræ. (April.)	'Wolsingham Observatory Circ.' No. xxiii.; 'Nature,' xxxix. 567 (Abs.)
J. N. Lockyer .	On the Wave-Length of the Chief Fluting seen in the Spectrum of Manganese. (Recd. April 6. Read May 2.)	'Proc. Roy. Soc.' xlvi. 35–40; 'Beiblätter,' xiii. 812 (Abs.)
W. Huggins and Mrs. Huggins.	On the Spectrum, Visible and Photographic, of the Great Nebula in Orion. (Recd. April 11. Read May 2.)	'Proc. Roy. Soc.' xlvi. 40–60; 'Nature,' xl. 405–407, 429–432.
T. E. Espin . .	The Spectrum of χ Cygni. (May.)	'Wolsingham Observ. Circ.' No. xxiv.; 'Nature,' xl. 135 (Abs.)
J. N. Lockyer .	Note sur le spectre d'Uranus. (Read June 3.)	'C. R.' cviii. 1149–1151; 'Beiblätter,' xiii. 688 (Abs.)
W. Huggins and Mrs. Huggins.	Note on the Photographic Spectra of Uranus and Saturn. (Recd. June 5. Read June 6.)	'Proc. Roy. Soc.' xlvi. 231–233; 'Beiblätter,' xiii. 949 (Abs.)

Astronomical Applications, 1889.

W. Huggins . .	'Sur le spectre photographique d'Uranus. (Read June 17.)	'C. R.' cviii. 1228–1229; 'Beiblätter,' xiii. 688 (Abs.)
J. N. Lockyer .	On the Cause of Variability in condensing Swarms of Meteorites. (Recd. June 27.)	'Proc. Roy. Soc.' xliv. 401–423; 'Beiblätter,' xiv. 515–516 (Abs.)
" .	Further Discussion of the Sun-spot Observations made at South Kensington. (Recd. June 27.)	'Proc. Roy. Soc.' xlvi. 385–401; 'Beiblätter,' xiv. 513 (Abs.)
J. E. Keeler . .	On the Spectra of Saturn and Uranus. (July 18.)	'Astr. Nachr.' cxxii. 401–404.
J. Fènyi . .	Deux éruptions sur le Soleil. (Recd. July 22.)	'C. R.' cix. 132–133; 'Beiblätter,' xiii. 885 (Abs.)
J. Scheiner . .	Vorläufige Mittheilung über Untersuchungen an photographischen Aufnahmen von Sternspectren. (July.)	'Astr. Nachr.' cxxii. 321–344; 'Nature,' xli. 163–164 (Abs.); 'Beiblätter,' xiii. 949–950 (Abs.)
G. Spörer . .	Lettere al Prof. Riccò sulle macchie solari del Giugno 1889. (Aug.)	'Mem. spettroscop. ital.' xviii. 185–188.
C. V. Zenger . .	La spectrophotographie des parties invisibles du spectre solaire. (Read Sept. 9.)	'C. R.' cix. 434–436; 'Nature,' xl. 539 (Abs.); 'Chem. News,' lx. 184–185 (Abs.)
E. C. Pickering .	Southern Stars having Peculiar Spectra. Spectrum of Pleione. (Sept.)	'Astr. Nachr.' cxxiii. 95–96; 'Nature,' xli. 115 (Abs.)
T. E. Espin . .	The Spectrum of R Andromedæ. (Oct. 31.)	'Nature,' xl. 656.
A. Riccò . .	Le macchie solari di Giugno, 1889. (Oct.)	'Mem. spettroscop. ital.' xviii. 180–184; 'Nature,' xli. 115 (Abs.)
A. M. Clerke . .	The Spectra of the Orion Nebula and of the Aurora. (Oct.)	'Observatory,' 1889, 366–370.
H. C. Vogel . .	Lettere al Prof. Riccò sulle macchie solari del Giugno 1889.	'Mem. spettroscop. ital.' xviii. 198; 'Nature,' xli. 233 (Abs.)
E. C. Pickering .	On the Spectrum of ζ Ursæ Majoris. (Read Nov. 13.)	'Amer. J. Sci.' xxxix. 46–47; 'Observatory,' xiii. 80–81.
J. N. Lockyer .	Further Discussion of the Sun-spot Observations made at South Kensington. A Report of the Solar Physics Committee. (Recd. June 27. Read Nov. 21.)	'Proc. Roy. Soc.' xlvi. 385–401.
H. C. Vogel and J. Scheiner.	Resultate spectrographischer Beobachtungen des Sterns Algol. (Read Nov. 28.)	'Sitzungsb. Akad. Berl.' 1889 [Phys.-math.], 1045; 'Nature,' xli. 164 (Abs.)
A. L. Cortie . .	Notes on the Spectrum of the Sun-Spot of June, 1889. (Dec.)	'Month. Not. Roy. Ast. Soc.' l. 64–65, 331–332; 'Nature,' xliii. 210 (Abs.)

ASTRONOMICAL APPLICATIONS, 1889, 1890.

A. Fowler	Objects for the Spectroscope. (Nov.–Dec.)	'Nature,' xli. 20, 44–45, 68, 87–88, 114–115, 138–139, 163, 183.
J. N. Lockyer	Comparison of the Spectra of Nebulæ and Stars of Groups I. and II. with those of Comets and Auroræ. (Recd. Nov. 9. Read Dec. 19.)	'Proc. Roy. Soc.' xlvii. 28–39; 'Beiblätter,' xiv. 516 (Abs.)
„	The Presence of Bright Carbon Flutings in the Spectra of Celestial Bodies. (Recd. Nov. 23. Read Dec. 19.)	'Proc. Roy. Soc.' xlvii. 39–41; 'Beiblätter,' xiv. 516 (Abs.)
A. Riccò	Osservazioni astrophysiche solari. Nova nella nebulosa di Andromeda. Nova presso χ Orionis.	'Mem. spettroscop. ital.' xvii. 135–140.
P. Tacchini	Macchie e facole solari osservate nel Regio Osservatorio del Collegio Romano, nel 3° trimestre del 1889.	'Mem. spettroscop. ital.' xviii. 191–197; 'Nature,' xli. 233–234 (Abs.)
E. C. Pickering	The Henry Draper Memorial. Third Annual Report of the Photographic Study of Stellar Spectra, conducted at Harvard College Observatory. (8 pp.)	'Nature,' xl. 17–18 (Abs.)
W. H. M. Christie	Spectroscopic Results . . .	'Greenwich Observ. Report,' 1888, lxxxv., lxxxvi. 1–19; 'Nature,' xlii. 209 (Abs.)
H. Crew	On the Period of the Sun's Rotation. (Haverford College Studies, 1889. 12 pp.)	'Beiblätter,' xiii. 884 (Abs.)

1890.

E. C. Pickering	On the Spectrum of ζ Ursæ Majoris. (Jan.)	'Amer. J. Sci.' [3], xxxix. 46–47; 'Nature,' xli. 285–286 (Abs.); 'Beiblätter,' xiv. 515 (Abs.)
H. C. Vogel	Spectroscopische Beobachtungen an Argol. (Jan.)	'Astr. Nachr.' No. 2947, 289–292; 'Nature,' xli. 286 (Abs.); 'Beiblätter,' xiv. 283–284, 789 (Abs.)
J. N. Lockyer	On the Chief Line in the Spectrum of the Nebulæ. (Recd. Dec. 9, 1889. Read Jan. 16, 1890. Revised May 1890.)	'Proc. Roy. Soc.' xlviii. 167–198.
„	Preliminary Note on Photographs of the Spectrum of the Nebula in Orion. (Recd. and read Feb. 13.)	'Proc. Roy. Soc.' xlviii. 199–201.
„	Note on the Spectrum of the Nebula of Orion. (Received and read Feb. 13.)	'Proc. Roy. Soc.' xlviii. 198–199.
J. Scheiner	Untersuchungen über die Sternspectra vom I Typus auf Grund von photographischen Aufnahmen. (Feb. 13.)	'Sitzungsb. Akad. Berl.' 1890, 143–151; 'Beiblätter,' xiv. 514 (Abs.)

ASTRONOMICAL APPLICATIONS, 1890.

E. C. Pickering	The Spectra of δ and μ Centauri. (Feb.)	'Astr.' Nachr.' No. 2951, 363; 'Nature,' xli. 374 (Abs.)
Maxwell Hall	Spectrum of the Zodiacal Light. (Feb.)	'Observatory,' xiii. 77–79; 'Nature,' xli. 351 (Abs.); 'Beiblätter,' xiv. 377 (Abs.)
T. W. Backhouse	The Spectrum of Borelli's Comet (*g* 1889). (Feb.)	'Observatory,' xiii. 90; 'Nature,' xli. 374 (Abs.)
E. C. Pickering	Observations of ζ Ursæ Majoris. (Feb.)	'Sidereal Messenger,' ix. 80–82; 'Nature,' xli. 403 (Abs.)
A. Fowler	Note on the Zodiacal Light. (Feb.)	'Nature,' xli. 402–403.
A. A. Rambaut	On the Parallax of Double Stars. (March.)	'Monthly Not. Roy. Astron. Soc.' l. 303–310; 'Nature,' xlii. 112–113 (Abs.)
W. Huggins and Mrs. Huggins.	On a Re-determination of the Principal Line in the Spectrum of the Nebula in Orion, and on the Character of the Line. (Recd. March 20. Read June 12.)	'Proc. Roy. Soc.' xlviii. 202–213.
H. C. Vogel	Bahnbewegung des Sterns α Virginis. (Read April 24.)	'Sitzungsb. Akad. Berl.' xxii. 401-402; 'Nature,' xlii. 90 (Abs.); 'Beiblätter,' xiv. 622 (Abs.)
C. Michie Smith	Notes on the Zodiacal Light. (April.)	'Proc. Roy. Soc. Edinb.' xvii. 142–146; 'Nature,' xliii. 22 (Abs.)
E. C. Pickering	On a New Variable Star in Cœlum. (April.)	'Astr. Nachr.' No. 2962, 175; 'Nature,' xli. 571 (Abs.)
N. C. Dunér	Sur la rotation du soleil. (May.)	'Astr. Nachr.' No. 2968, 267–270; 'Nature,' xlii. 138 (Abs.); 'Beiblätter,' xiv. 620 (Abs.)
A. Fowler	Objects for the Spectroscope.	'Nature,' xlii. 20, 37, 67–68, 89–90, 111–112, 137–138, 161–162, 182, 208–209, 235–236, 281–282, 303, 330, 354, 377, 404, 428, 459–460, 489, 511, 526, 555, 576, 600, 619.
„	The Spectrum of Comet Brooks (*a* 1890). (May.)	'Nature,' xlii. 112.
J. N. Lockyer	On the Spectra of Comet *a* 1890 and the Nebula G. C. 4058. (Recd. June 12. Read June 12.)	'Proc. Roy. Soc.' xlviii. 217–220.
A. Fowler	The Spectrum of Comet Brooks (*a* 1890). (June.)	'Nature,' xlii. 162.
W. Huggins and Mrs. Huggins.	Note on the Photographic Spectrum of the Great Nebula in Orion. (Recd. April 16. Read June 12.)	'Proc. Roy. Soc.' xlviii. 213–216.

ASTRONOMICAL APPLICATIONS, 1890.

W. Huggins and Mrs. Huggins.	On a New Group of Lines in the Photographic Spectrum of Sirius. (Recd. April 25. Read June 12.)	'Proc. Roy. Soc.' xlviii. 216–217.
W. Huggins	Sur le spectre visible et photographique de la grande nébuleuse d'Orion. (Read June 23.)	'C. R.' cx. 1310–1311; 'Nature,' xlii. 240 (Abs.); 'Beiblätter,' xiv. 790 (Abs.)
J. Janssen	Sur l'éclipse partielle du soleil du 17 juin. (Read June 23.)	'C. R.' cx. 1290–1292; 'Nature,' xlii. 256 (Abs.); 'Chem. News,' lxii. 38 (Abs.); 'Beiblätter,' xix. 787 (Abs.)
W. Huggins	Sur le spectre photographique de Sirius. (Read June 30.)	'C. R. cx. 1357–1358 'Nature,' xlii. 263 (Abs.); 'Chem. News,' lxii. 38 (Abs.); 'Beiblätter,' xiv. 790 (Abs.)
E. A. B. Mouchez	Photographies spectrales d'étoiles de MM. Henry, de l'Observatoire de Paris. (Read July 7.)	'C. R.' cxi. 5–6; 'Nature, xlii. 282 (Abs.); 'Beiblätter,' xiv. 789 (Abs.)
H. C. Vogel	Ueber die Bahnbewegung von α Virginis. (July.)	'Astr. Nachr.' No. 2995, 305–316; 'Nature,' xliii. 235–237 (Abs.)
L. Becker	The Solar Spectrum at Medium and Low Altitudes. (Read July 21.)	'Trans. Roy. Soc. Edinb.' xxxvi. 99–210; 'Nature,' xliii. 399–400 (Abs.)
A. de la Baume Pluvinel.	Sur l'observation de l'éclipse annulaire du soleil du 17 juin 1890. (Read July 28.)	'C. R.' cxi. 220–222; 'Nature,' xlii. 360 (Abs.)
E. C. Pickering	Stars having Peculiar Spectra. (Aug.)	'Astr. Nachr.' No. 2986, 155–156; 'Nature,' xlii. 429 (Abs.)
C. Piazzi Smyth	Photographs of the Invisible in Solar Spectrography. (Read Sept. 8.)	'Brit. Assoc. Rep.' 1890, 750–751; 'Beiblätter,' xvi. 279 (Abs.)
J. N. Lockyer	Comparison of the Spectra of Nebulæ and Stars of Groups I. and II. with those of Comets and Auroræ. (Aug.)	'Nature,' xlii. 342–345, 393–397.
"	On Stellar Variability. (Aug.)	'Nature,' xlii. 415–419.
J. Janssen	Compte rendu d'une ascension scientifique au Mont-Blanc. (Read Sept. 22.)	'C. R.' cxi. 431–447; 'Nature,' xlii. 555 (Abs.)
E. C. Pickering	Stars having Peculiar Spectra. (Oct.)	'Astr. Nachr.' No. 2997, 363–364; 'Nature,' xlii. 619 (Abs.)
"	Stars having Peculiar Spectra, including New Variables in Triangulum and Hydra. (Oct.)	'Astr. Nachr.' No. 3008, 117–120; 'Nature,' xliii. 184 (Abs.)
"	Stars having Peculiar Spectra. (Oct.)	'Astr. Nachr.' No. 3011, 166; 'Nature,' xliii. 280 (Abs.)

ASTRONOMICAL APPLICATIONS, 1890, 1891.

G. E. Hale	Note on Solar Prominence Photography. (Oct.)	'Astr. Nachr.' No. 3006, 81–82; 'Nature,' xliii. 133 (Abs.)
A. Fowler	The Duplicity of α Lyræ. (Nov.)	'Month. Not. Roy. Astron. Soc.' li. 8–11; 'Nature,' xliii. 64–65 (Abs.)
A. L. Cortie	Spectroscopic Notes and Queries. (Nov.)	'Month. Not. Roy. Ast. Soc.' li. 18–23.
T. E. Espin	On the Variation of the Spectra of R Coronæ and R Scuti, and on the Spectra of R Aurigæ and R Andromedæ. (Nov.)	'Month. Not. Roy. Ast. Soc.' li. 11–13; 'Nature,' xliii. 165 (Abs.)
F. McClean	Comparative Photographs of the High Sun and Low Sun Visible Spectra, with Notes on the Method of Photographing the Red End of the Spectrum. (Nov.)	'Month. Not. Roy. Ast. Soc.' li. 13–17.
G. Higgs	Photograph of the A Line in the Solar Spectrum. (Nov.)	'Month. Not. Roy. Ast. Soc.' li. 18.
W. Huggins and Mrs. Huggins.	On Wolf and Rayet's Bright-Line Stars in Cygnus. (Recd. Nov. 25. Read Dec. 11.)	'Proc. Roy. Soc.' xlix. 33–46; 'Chem. News,' lxiii. 27–30, 39–40.
A. L. Cortie	Observations of the Spectra of Sun-Spots in the Region B–D, made at the Stonyhurst College Observatory in the Years 1882–1889. (Dec.)	'Month. Not. Roy. Ast. Soc.' li. 76–78 (Abs.); 'Nature,' xliii. 256–257 (Abs.)
M. Fleming	Stars having Peculiar Spectra. (Dec.)	'Astr. Nachr.' No. 3025 [6]; 'Nature,' xliii. 545 (Abs.)
L. Thollon	Nouveau dessin du spectre solaire.	'Annales de l'Observ. de Nice,' iii. A7–A112; 'Nature,' xlii. 303 (Abs.)
J. Janssen	Sur le spectre de l'oxygène	'Vierteljahrb. d. Astron. Gesellsch.' xxv. 2–5.
N. von Konkoly	Spectroscopische Beobachtung des Kometen Sawerthal.	'O'Gyalla Observations,' 1888–9; 'Nature,' xlii. 650 (Abs.)
E. C. Pickering	The Draper Catalogue of Stellar Spectra.	'Annals of Harvard Coll. Observ.' xxvii. 1–388; 'Nature,' xliv. 89–90 (Abs.)
W. H. M. Christie	Greenwich Spectroscopic Observations for 1889.	'Nature,' xliii. 210 (Abs.)

1891.

H. Deslandres	Sur le spectre de α Lyræ. (Read Feb. 23.)	'C. R.' cxii. 413–414; 'Nature,' xliii. 432 (Abs.); 'Chem. News,' lxiii. 131 (Abs.)
H. A. Rowland	Report of Progress in Spectrum Work. (Feb.)	'Johns Hopkins Univ. Circ.' No. 85, 41–42; 'Nature,' xliii. 452–453 (Abs.)
E. C. Pickering	A Fifth Type of Stellar Spectra. (Feb.)	'Astr. Nachr.' No. 3025, 1–2.

ASTRONOMICAL APPLICATIONS, 1891.

J. E. Keeler . .	On the Chief Line in the Spectrum of the Nebulæ. (Recd. March 13. Read March 19.)	'Proc. Roy. Soc.' xlix. 399–403.
J. N. Lockyer .	On the Causes which produce the Phenomena of New Stars. (Recd. Nov. 28, 1890. Read April 16, 1891.)	'Proc. Roy. Soc.' xlix. 443–446 (Abs.)
E. C. Pickering .	The Discovery of Double Stars by their Spectra. (May.)	'Astr. Nachr.' No. 3034, 155–156; 'Nature,' xliv. 138 (Abs.)
J. Kleiber . .	Ueber die mittlere Entfernung derjenigen Sterne deren eigene Bewegung im Visionsradius bekannt ist. (May.)	'Astr. Nachr.' cxxvii. No. 3037, 209–212; 'Beiblätter,' xvii. 753–754 (Abs.)
T. E. Espin . .	Photo-Stellar Spectra. (June.)	'Nature,' xliv. 133–134.
E. C. Pickering .	Stars having Peculiar Spectra. (July.)	'Astr. Nachr.' No. 3049, 11–14; 'Nature,' xliv. 305 (Abs.)
" .	The Spectrum of β Lyræ. (Aug.) .	'Astr. Nachr.' No. 3051, 39–42; 'Nature,' xliv. 355 (Abs.)
" .	On Stars having Peculiar Spectra. (Aug.)	'Astr. Nachr.' No. 3054, 121–122; 'Nature,' xliv. 438 (Abs.)
G. E. Hale . .	Photographic Investigation of Solar Prominences and their Spectra. (Aug.)	'Amer. J. Sci.' [3], xlii. 160–166; 'Nature,' xliv. 439 (Abs.)
T. E. Espin . .	On Nova Aurigæ. (Aug.) . .	'Wolsingham Observ. Circ.' No. 33; 'Nature,' xlvi. 400 (Abs.)
H. Deslandres .	Recherches nouvelles sur l'atmosphère solaire. (Read Aug. 17.)	'C. R.' cxiii. 307–310; 'Chem. News,' lxiv. 125 (Abs.)
C. Piazzi Smyth .	Report of the Committee on Researches upon the Ultra-Violet Rays of the Solar Spectrum. (Read Aug. 24.)	'Brit. Assoc. Rep.' 1891, 147–148; 'Beiblätter,' xvi. 610 (Abs.)
G. E. Hale . .	The Ultra-Violet Spectrum of the Solar Prominences. (Aug.)	'Brit. Assoc. Rep.' 1891, 557–558; 'Amer. J. Sci.' [3], xlii. 459–467.
H. Fizeau . .	Remarques sur l'influence que l'aberration de la lumière peut exercer sur les observations des protubérances solaires par l'analyse spectrale. (Sept.)	'C. R.' cxiii. 353–356; 'Nature,' xliv. 530 (Abs.)
E. L. Trouvelot .	Chute d'une protubérance solaire dans l'ouverture d'une tache. (Read Oct. 5.)	'C. R.' cxiii. 437–438; 'Nature,' xlvi. 258 (Abs.)
C. A. Young . .	Note on the Chromospheric Spectrum. (Oct. 20.)	'Nature,' xlv. 28.
E. W. Maunder .	The Chief Nebular Line. (Oct.) .	'J. Brit. Astron. Assoc.' i. 25–33; 'Nature, xliii. 165 (Abs.)

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E. C. Pickering	The Distribution of Energy in Stellar Spectra. (Oct.)	'Astr. Nachr.' cxxviii. No. 3069, 377–380; 'Nature,' xlv. 159 (Abs.); 'Beiblätter,' xviii. 97–98 (Abs.)
A. L. Cortie	The Chromospheric Line Ångström 6676·9. (Nov. 19.)	'Nature,' xlv. 103–104.
H. Deslandres	Recherches sur le mouvement radial des astres avec le sidérostat de l'Observatoire de Paris. (Read Nov. 23.)	'C. R.' cxiii. 737–739; 'Nature,' xlv. 117 (Abs.)
M. Fleming	Stars having Peculiar Spectra. Group of Stars of the Fifth Type in Cepheus. (Nov.)	'Astr. Nachr.' No. 3070, 403–404; 'Nature,' xlv. 210 (Abs.)
C. A. Young	The Chromospheric Line λ 6676·9. (Dec. 16.)	'Nature,' xlv. 198.
H. C. Vogel	On the Spectrographic Method of Determining the Velocity of Stars in the Line of Sight. (Dec.)	'Month. Not. Roy. Ast. Soc.' lii. 87–96; 'Nature,' xlv. 280–281 (Abs.)
A. Cornu	Sur la méthode Doppler-Fizeau	'Annuaire du Bureau de Longitudes,' 1891, D1–D40.

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H. Deslandres	Recherches nouvelles sur l'atmosphère solaire. (Read Feb. 8.)	'C. R.' cxiv. 276–277; 'Beiblätter,' xvii. 565–566 (Abs.)
J. Scheiner	Berichtigungen zu 'Die Spectralanalyse der Gestirne.' (April.)	'Astr. Nachr.' cxxix. No. 3082, 157–160; 'Beiblätter,' xvii. 129 (Abs.)
E. W. Maunder	Spectrum of Nova Aurigæ	'Nature,' xlv. 616–617.
W. Huggins	The New Star in Auriga. (Read May 13.)	'Proc. Roy. Inst.' xiii. 615–624.
W. Huggins and Mrs. Huggins.	On the New Star in Auriga. (Read May 19.)	'Proc. Roy. Soc.' li. 486–495; 'Beiblätter,' xvii. 449 (Abs.)
G. E. Hale	Photographies de la chromosphère, des protubérances et des facules solaires, prises à l'Observatoire d'Astronomie Physique de Kenwood, Chicago. (Read July 11.)	'C. R.' cxv. 106–109.
H. Deslandres	Résultats nouveaux sur l'hydrogène, obtenus par l'étude spectrale du soleil. Rapprochements avec l'étoile nouvelle du Cocher. (Read July 25.)	'C. R.' cxv. 222–225; 'Nature,' xlvi. 401 (Abs.); 'Beiblätter,' xvii. 556 (Abs.)
H. Seeliger	Ueber den neuen Stern im Sternbilde Auriga. (July.)	'Astr. Nachr.' No. 3118, 392–406; 'Nature,' xlvii. 137–140.
C. Piazzi Smyth	Second Report of the Committee appointed to co-operate with Dr. C. Piazzi Smyth in his Researches on the Ultra-Violet Rays of the Solar Spectrum. (Aug.)	'Brit. Assoc. Rep.' 1892, 74–76; 'Beiblätter,' xvii. 829–830 (Abs.)

ASTRONOMICAL APPLICATIONS, 1892, 1893.

H. F. Newall	The Nova Aurigæ. (Sept.)	'Nature,' xlvi. 489.
E. von Gothard	Ueber die Nova Aurigæ. (Sept.)	'Astr. Nachr.' cxxx. No. 3122, 27–28; 'Nature,' xlvi. 620 (Abs.)
A. Belopolsky	Nova Aurigæ. (Oct.)	'Astr. Nachr.' cxxx. No. 3120, 437–438; 'Nature,' xlvi. 552, 576 (Abs.)
H. F. Newall	Nova Aurigæ. (Oct.)	'Nature,' xlvii. 7.
H. Deslandres	Transformation du grand télescope de l'Observatoire de Paris pour l'étude des vitesses radiales des astres. Résultats obtenus. (Read Nov. 14.)	'C. R.' cxv. 783–786; 'Beiblätter,' xviii. 340 (Abs.); 'Nature,' xlvii. 88, 115 (Abs.)
J. N. Lockyer	On the Photographic Spectra of some of the Brighter Stars. (Read Dec. 8.)	'Phil. Trans.' clxxxiv. 675–726; 'Proc. Roy. Soc.' lii. 326–331 (Abs.); 'Nature,' xlvii. 261–263 (Abs.); 'Beiblätter,' xvii. 831 (Abs.)
E. von Gothard	Studien über den photographischen Spectrum der planetarischen Nebel und des neuen Stern. (Dec.)	'Mem. spettroscop. ital.' xxi. 169–171; 'Nature,' xlvii. 352 (Abs.)
G. E. Hale	The Ultra-Violet Spectrum of the Solar Prominences. (Dec.)	'Mem. spettroscop. ital.' xxi. 160–161; 'Nature,' xlvii. 186 (Abs.)
C. E. Stromeyer	Measurement of Distances of Binary Stars. (Dec.)	'Nature,' xlvii. 199.
A. A. Rambaut	Measurement of Distances of Binary Stars. (Dec.)	'Nature,' xlvii. 226.
W. H. M. Christie	Results of the Spectroscopic Observations made at Greenwich in the Year 1890.	'Greenwich Observ. Report,' 1890, 28 pp.

1893.

J. Janssen	Remarques sur une note de M. Dunér intitulée 'Y a-t-il de l'oxygène dans l'atmosphère du soleil?' (Read Jan. 8.)	'C. R.' cxviii. 54–56; 'Ber. xxvii. (Ref.), 108 (Abs.); 'Chem. News,' lxix. 49 (Abs.)
G. E. Hale	Les raies H et K dans le spectre des facules solaires. (Read Jan. 30.)	'C. R.' cxvi. 170–172.
H. C. Vogel	Versuch einer Ableitung der Bewegung des Sonnensystems aus den Potsdamer spectrographischen Beobachtungen. (Feb.)	'Astr. Nachr.' cxxxii. 81–82; 'Beiblätter,' xvii. 1055–1056 (Abs.)
W. Huggins	Note on the Spectrum of Nova Aurigæ. (Feb.)	'Astr. Nachr.' cxxxii. No. 3153, 143–144; 'Nature,' xlvii. 425 (Abs.)
V. Schumann	The Hydrogen Line H_β in the Spectrum of Nova Aurigæ, and in the Spectrum of Vacuum-tubes. (Feb.)	'Astron. and Astrophys.' xii. 159–166; 'Beiblätter,' xvii. 826–827 (Abs.)

J. Janssen	Sur la méthode spectrophotographique qui permet d'obtenir la photographie de la chromosphère, des facules, des protubérances, etc. (Read March 6.)	'C. R.' cxvi. 456–457.
G. E. Hale	Méthode spectrographique pour l'étude de la couronne solaire. (Read April 24.)	'C. R.' cxvi. 865–866; 'Beiblätter,' xvii. 931–932 (Abs.)
E. von Oppolzer	Zur Frage der Rotationsdauer der Venus. (June.)	'Astr. Nachr.' cxxxiii. No. 3170, 39–40; 'Nature,' xlviii. 233 (Abs.)
T. E. Espin	Stars with Remarkable Spectra. (June.)	'Astr. Nachr.' cxxxiii. No. 3171, 43–48; 'Nature,' xlviii. 233 (Abs.)
W. Huggins and Mrs. Huggins.	On the Bright Bands in the Present Spectrum of Nova Aurigæ. (Read June 8.)	'Proc. Roy. Soc.' liv. 30–36.
A. de la Baume Pluvinel.	Sur l'observation de l'éclipse totale du soleil du 16 avril, fait à Joal (Sénégal). (Read July 3.)	'C. R.' cxvii. 24–27; 'Beiblätter,' xviii. 93 (Abs.)
J. Janssen	Note sur l'historique des faits qui ont démontré l'existence de l'atmosphère coronale du soleil. (Read July 10.)	'C. R.' cxvii. 77–80; 'Beiblätter,' xviii. 94 (Abs.)
G. J. Stoney	Note on Observing the Rotation of the Sun with the Spectroscope. (Aug.)	'Brit. Assoc. Rep.' 1891, 573–574; 'Beiblätter,' xvii. 931 (Abs.)
J. Janssen	Sur les observations spectroscopiques faites à l'Observatoire du Mont-Blanc les 14 et 15 Septembre 1893. (Read Sept. 25.)	'C. R.' cxvii. 419–423; 'Chem. News,' lxviii. 185 (Abs.)
E. Dunér	Y a-t-il de l'oxygène dans l'atmosphère du soleil?' (Read Dec. 26.)	'C. R.' cxvii. 1056–1059; 'Chem. News,' lxix. 25 (Abs.); 'Ber.' xxvii. (Ref.), 43 (Abs.)

1894.

A. Schuster	Y a-t-il de l'oxygène dans l'atmosphère du soleil?' (Read Jan. 15.)	'C. R.' cxviii. 137–138; 'Chem. News,' lxix. 61 (Abs.)

VII.

METEOROLOGICAL APPLICATIONS.

1882.

C. C. Krafft	Spectroscopische Untersuchungen.	'Beobachtungsergebnisse der Norwegischen Polarstation Bossekop in Alten,' 1882–3, II. Theil, 'Nordlicht,' 10–11; 'Nature,' xxxix. 515–516 (Abs.)

Meteorological Applications, 1883, 1884, 1885, 1888, 1889, 1890.

1883.

C. E. Cook	The Use of the Spectroscope in Meteorology. (Oct.)	'Science,' ii. 488–491; 'Zeitschr. f. Instrumentenkunde, iv. 102–103 (Abs.)

1884.

S. P. Langley	On the Amount of the Atmospheric Absorption. (April.)	'Amer. J. Sci.' [3], xxviii. 163–180; 'Phil. Mag.' [5], xviii. 289–307; 'Nature,' xxxi. 46 (Abs.); 'J. Chem. Soc.' xlviii. 319 (Abs.); 'J. de Phys.' [2], iv. 95–97 (Abs.); 'Beiblätter,' ix. 335–336 (Abs.)
C. Michie Smith	Observations on a Green Sun and Associated Phenomena. (Read July 7.)	'Trans. Roy. Soc. Edinb.' xxxii. 389–409; 'Nature,' xxx. 347–349.

1885.

W. W. Lermantoff	Ueber die Regenbande im Spectrum der Atmosphäre. (Read Jan. 29, O.S. (In Russian.)	'J. Russ. Phys.-Chem. Soc.,' xvii. [Phys.], No. 2, pp. 44–45.
E. L. Nichols	A Spectro-photometric Analysis of the Colour of the Sky. (Aug.)	'Proc. Amer. Assoc.' xxxiv. 78–79.
N. Egoroff	Das Absorptionspectrum der Atmosphäre. (In Russian.) (Read Sept. 24, O.S.)	'J. Russ. Phys.-Chem. Soc.' xvii. [Phys.], No. 7, p. 229.

1888.

C. Rovelli	Le tinte dei crepuscoli in relazione collo stato igrometrico dell' atmosfera. (Jan.)	'Riv. scientifico-industriale,' xx. 1–5; 'Nature,' xxxvii. 404 (Abs.)

1889.

J. Janssen	Sur l'origine tellurique des raies de l'oxygène dans le spectre solaire. (Read May 20.)	'C. R.' cviii. 1035–1037; 'Nature,' xl. 104; 'Chem. News,' lix. 281; 'Beiblätter,' xiii. 682–683 (Abs.)
A. Crova	Sur l'analyse de la lumière diffusée par le ciel. (Read Sept. 23.)	'C. R.' cix. 493–496; 'Nature,' xl. 563 (Abs.); 'Beiblätter,' xiv. 37 (Abs.)

1890.

C. S. Cook	A Mountain Study of the Spectrum of Aqueous Vapour. (April.)	'Amer. J. Sci.' [3], xxxix. 258–268; 'Nature,' xli. 598 (Abs.); 'Beiblätter,' xiv. 782–786 (Abs.)
W. E. Wood	Lightning Spectra. (June.)	'Sidereal Messenger,' ix. 285; 'Nature,' xlii. 236 377–378 (Abs.)

G. Higgs	Recent Photographs of the Less Refrangible Portions of the Solar Spectrum under Different Atmospheric Conditions. (Read Sept. 10.)	'Brit. Assoc. Rep.' 1890, 760; 'Beiblätter,' xvi. 279 (Abs.)
J. Janssen	Compte rendu d'une ascension scientifique au Mont-Blanc. (Read Sept. 22.)	'Annuaire du Bureau des Longitudes,' 1891, A18–A24; 'C. R.' cxi. 431–447; 'Chem. News,' lxii. 202 (Abs.)
"	Le spectre de l'atmosphère terrestre. (Sept.)	L'Astronomie,' ix. 337–338; 'Nature,' xlii. 526 (Abs.)
A. Cornu	Sur la limite ultraviolette du spectre solaire, d'après des clichés obtenus par M. le Dr. O. Simony au sommet du pic de Ténériffe. (Read Dec. 22.)	'C. R.' cxi. 941–947; 'Nature,' xliii. 216 (Abs.); 'Chem. News,' lxiii. 36 (Abs.)

1891.

A. Crova	Analyse de la lumière diffusée par le ciel. (Read June 1.)	'C. R.' cxii. 1176–1179, 1246–1247; 'Phil. Mag.' [5], xxxii. 141–144 (Abs.); 'Ann. Chim. et Phys. [6], xxv. 534–567.
W. E. Wood	Lightning Spectra. (Aug.)	'Sidereal Messenger,' x. 378–380; 'Nature,' xliv. 504 (Abs.)
G. B. Rizzo	Le linee telluriche dello spettro solare.	'Mem. spettroscop. ital.' xx. 77–86; 'Nature,' xliv. 186–187 (Abs.)

1892.

N. Piltschikoff	Sur la polarisation spectrale du ciel. (Read Oct. 17.)	'C. R.' cxv. 555–558; 'Beiblätter,' xvii. 337 (Abs.)

VIII.

CHEMICAL RELATIONS.

1875.

R. Amory	On Photographs of the Solar Spectrum. (Read May 25.)	'Proc. Amer. Acad.' [N.S.], iii. 70.

1876.

"	On Photographs of the Solar Spectrum. (Read May 10.)	'Proc. Amer. Acad.' [N.S.], iii. 279–280.

1877.

"	On the Photographic Action of Dry Silver Bromide Collodion, &c., to Rays of Solar Light of Different Refrangibility. (Presented June 10.)	'Proc. Amer. Acad.' [N.S.] v. 171–174.

Chemical Relations, 1880, 1881, 1882, 1883, 1884.

1880.

M. Coulier . .	Le spectroscope appliqué aux sciences chimiques et pharmaceutiques.	'J. de Pharm.' [4], xxx. 541–544; [5], i. 24–30, 118–128, 319–327, 393–400; ii. 18–31, 221–223, 285–294, 376–388, 455–465; iii. 126–138, 220–228, 403–410, 545–548.

1881.

L. Palmieri . .	Della riga dell' Helium apparsa in una recente sublimazione vesuviana. (Read Nov. 5.)	'Rendic. Accad. Napoli,' xx. 233.
W. de W. Abney .	On the Effect of the Spectrum on the Haloid Salts of Silver and on Mixtures of the same. (Recd. Dec. 6.)	'Proc. Roy. Soc.' xxxiii. 164–186; 'J. Phot. Soc.' vi. 136–151; 'Phot. Mittheil.' 130–131 (Abs.); 'Beiblätter,' v. 872 (Abs.)

1882.

H. W. Vogel . .	Ueber eine Substanz zur Erkennung der chemischen Wirkung des gelben Lichtes. (Feb.)	'Phot. Mittheil.' xviii. 300–301; 'Beiblätter,' vi. 490 (Abs.)
F. Osmond and G. Witz.	Etudes sur l'industrie du vanadium ('Bull. Soc. Industr. de Rouen'). (March.)	'Rev. des Industr. chim. et agric.' vi. 480–494, 513–530; 'Chem. News,' xlvii. 12–13 (Abs.)
H. W. Vogel . .	Ueber die verschiedenen Modificationen des Brom- und Chlorsilbers, und die Empfindlichkeit derselben gegen das Sonnenspectrum. (Read May 25.)	'Phot. Mittheil.' xix. 32–34; 'Beiblätter,' vi. 489 (Abs.)
„ . .	Lichtempfindlichkeit der Silberhaloidsalze gegen das Sonnenspectrum. (June.)	'Phot. Mittheil.' xix. 70–73, 94–97, 108–112; 'Beiblätter,' vii. 536–538 (Abs.)

1883.

H. Quincke . .	Ueber das Verhalten des Harns nach Gebrauch von Copaivabalsam. (Sept.)	'Arch. f. exp. Path. u. Pharmakol.' xvii. 273–277; 'Ber.' xvii. (Ref.), 178–179 (Abs.)

1884.

R. Nasini and O. Bernheimer.	Sulle relazioni esistenti tra il potere rifrangente e la constituzione chimica dei composti organici. (March.)	'Gazz. chim. ital.' xv. 59–105; 'Atti R. Accad. Lincei, Mem.' [3], xviii. 608–640; 'J. Chem. Soc.' xlviii. 1097 (Abs.); 'Ber.' xviii. (Ref.), 474–475 (Abs.); 'Beiblätter,' ix. 326–330 (Abs.)
W. H. Pickering .	Photography of the Infra-Red Region of the Solar Spectrum. (Presented May 14.)	'Proc. Amer. Acad.' [N.S.], xii. 473–477.

CHEMICAL RELATIONS, 1884, 1885, 1886, 1887.

J. Uffelmann	Spectroscopisch-hygienische Studien. (Oct.)	'Arch. f. Hygiène,' ii. 196–222; 'Chemiker-Zeitung,' viii. 1232; 'Zeitschr. f. anal. Chem.' xxiv. 626 (Abs.)

1885.

J. H. Gladstone	On the Specific Refraction and Dispersion of the Alums. (Read June 27.)	'Proc. Phys. Soc.' vii. 194–200; 'Phil. Mag.' [5], xx. 162–168.
S. v. Kostanecki and S. Niementowski.	Ueber die isomeren Dioxydimethylanthrachinone. (Recd. Aug. 5.)	'Ber.' xviii. 2138–2141; 'Beiblätter,' xiv. 513 (Abs.)

1886.

W. N. Hartley	Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra. Part VIII. A Study of Coloured Substances and Dyes. (Read Nov. 18.)	'J. Chem. Soc.' li. 152–202; 'Zeitschr. f. physikal. Chem.' ii. 855 (Abs.)
H. W. Vogel	Ueber neue Fortschritte in dem farbenempfindlichen photographischen Verfahren. (Read Nov. 25.)	'Sitzungsb. Akad. Berl.' 1886, 1205–1208; 'Verh. phys. Gesellsch. Berl.' VI. Jahrg. 11 (Abs.); 'Nature,' xxxv. 432 (Abs.)
E. Pringsheim	Ueber neuere Versuche die Kohlensäure ausserhalb der Pflanze durch Chlorophyll zu zerlegen. (Oct.)	'Chemiker-Zeitung,' x. 1241; 'Bied. Centralbl.' 1887, 168–169 (Abs.); 'J. Chem. Soc.' lii. 685 (Abs.)
W. Leube	Ueber einen neuen pathologischen Harnfarbstoff. (Nov.)	'Archiv f. path. Anat. und Physiol.' cvi. 418–419; 'Zeitschr. f. anal. Chem.' xxvi. 672 (Abs.); 'Chem. News,' lvii. 231 (Abs.)

1887.

W. Crookes	Genesis of the Elements. (Lect. Roy. Inst. Feb. 18.)	'Proc. Roy. Inst.' xii. 37–60; 'Chem. News,' lv. 83–88, 95–99.
R. Nasini	Sulla rifrazione moleculare delle sostanze organiche dotate di forte potere dispersivo. (Read Feb. 20.)	'Rendic. R. Accad. Lincei' [4], iii. 164–172; 'Zeitschr. f. physikal. Chem.' i. 422 (Abs.)
T. W. Best	On the Delicacy of Spectroscopic Reaction in Gases. (Manch. Lit. and Phil. Soc. Feb. 22.)	'Chem. News,' lv. 209–211; 'Dingler's polyt. J.' cclxiv. 407–408 (Abs.); 'Beiblätter,' xii. 102 (Abs.)
A. B. Griffiths and Mrs. Griffiths.	Investigations on the Influence of Certain Rays of the Solar Spectrum on Root-Absorption and on the Growth of Plants. (Read March 7.)	'Proc. Roy. Soc. Edinb.' xiv. 125–129; 'J. Chem. Soc.' liv. 623 (Abs.)

CHEMICAL RELATIONS, 1887, 1888.

A. Tschirch . .	Untersuchungen über das Chlorophyll. (Read March 16.)	'Ber. d. bot. Gesellsch.' v. 128–135; 'Chem. Centralbl.' 1887, 669 (Abs.); 'J. Chem. Soc.' lii. 1116–1117 (Abs.)
J. Dewar . .	Light as an Analytic Agent. (Lect. Roy. Inst., April 1.)	'Proc. Roy. Inst.' xii. 83–93; 'Beiblätter,' xiii. 79–80 (Abs.)
H. Dufet . .	Sur les volumes moléculaires et l'énergie réfractive des phosphates, arséniates et hypophosphites de soude. (Read May 10.)	'Soc. franç. de Phys.' 1887, 117–128; 'J. de Phys.' [2], vi. 301–312; 'Bull. Soc. franç. de Min.' x. 77–120; 'Ber.' xx. (Ref.), 530 (Abs.); 'Beiblätter,' xiii. 701–703 (Abs.)
„ . .	Sur les volumes moléculaires et l'énergie réfractive des phosphates, arséniates et hypophosphates de soude. (Read May 20.)	'Soc. franç. de Phys.' 1887, 117–128; 'J. de Phys.' [2], vi. 301–312; 'Ber.' xx. (Referate), 530 (Abs.); 'Beiblätter,' xiii. 701–703 (Abs.)
E. Kock . .	Zur Kenntniss der Beziehungen zwischen optischen Eigenschaften und Constitution der Verbindungen. (June.)	'Ann. Phys. u. Chem.' [N.F.], xxxii. 167–171; 'Zeitschr. f. physikal. Chem.' i. 669–670 (Abs.)
A. Hénocque . .	De l'influence des médications thermales sur l'activité de la réduction de l'oxyhémoglobine, et sur la richesse du sang en oxyhémoglobine. (Read Nov. 19.)	'C. R. de la Soc. Biol. de France' [8], iv. 678–683; 'Ber.' xxi. (Ref.), 373 (Abs.)
Th. W. Engelmann	Die Farben bunter Laubblätter und ihrer Bedeutung für die Zerlegung der Kohlensaüre im Lichte.	'Bot. Zeitung,' 1887, 393–398, 409–419, 441–450, 457–469; 'Onderzoekungen Physiol. Lab. Utrecht' [3], x. 107–168; 'Archives néerlandaises,' xxii. 1–57; 'Beiblätter,' xi. 709 (Abs.); 'Chem. News,' lvi. 279 (Abs.); 'J. Chem. Soc.' liv. 381–382 (Abs.)

1888.

F. Mangini . .	Probabile causa della valenza degli atomi. (Jan.)	'Riv. scientifico-industriale,' xx. 23–27; 'Nature,' xxxvii. 451 (Abs.)
L. Hermann . .	Notiz betreffend das reducirte Hämoglobin.	'Arch. f. d. gesammte Physiol.' xliii. 435; 'Ber.' xxii. [Ref.], 595 (Abs.)
C. A. Macmunn .	On the Origin of Urohæmatoporphyrin and of Normal and Pathological Urobilin in the Organism. (Read Mar. 17.)	'J. Physiol.' x. 71–121.
E. Lambling . .	Sur l'action réductrice exercée par l'indigo blanc sur l'oxyhémoglobine du sang. (Read April 28.)	'C. R. de la Soc. Biol. de France' [8], v. 394–396; 'J. Chem. Soc.' lvi. 530–531 (Abs.)

CHEMICAL RELATIONS, 1888.

R. Weegmann	Ueber die Molecularrefraction einiger gebromter Aethane und Aethylene, und über den gegenwärtigen Stand der Landolt-Brühl'schen Theorie' (Inaugural-Dissertation, Bonn. 1888, 44 pp.). (April.)	'Zeitschr. f. physikal. Chem.' ii. 218–240, 257–269.
W. N. Hartley	Researches on the Relation between the Molecular Structure of Carbon Compounds and their Absorption Spectra. Part ix. On Isomeric Cresols, Dihydroxybenzenes, and Hydroxybenzoic Acids. (Read May 18.)	'J. Chem. Soc.' liii. 641–663; 'Zeitschr. f. physikal. Chem.' ii. 974 (Abs.)
H. Vogel	Spectroscopische Notizen. (Read June 14.)	'Ber.' xxi. 2029–2032; 'Zeitschr. f. physikal. Chem.' ii. 655 (Abs.)
E. Lambling	Des applications de la spectrophotométrie à la chimie physiologique. (July.)	'Arch. de Physiol. normale et pathologique' [4], ii. 1–34, 384, 418; 'J. Chem. Soc.' lvi. 73 (Abs.)
C. Liebermann	Ueber Spectra der Aether der Oxyanthrachinone. (Recd. Aug. 1.)	'Ber.' xxi. 2527; 'Zeitschr. f. physikal. Chem.' ii. 967 (Abs.)
Th. W. Engelmann	Ueber Bacteriopurpurin und seine physiologische Bedeutung. (Aug.)	'Archiv f. d. ges. Physiol.' xlii. 183–186; 'J. Chem. Soc.' lvi. 180–181 (Abs.)
„	Ueber Blutfarbstoff als Mittel um den Gaswechsel von Pflanzen im Licht und Dunkel zu unterscheiden. (Aug.)	'Archiv f. d. ges. Physiol.' xlii. 186–188; 'J. Chem. Soc.' lvi. 182 (Abs.)
L. von Udránszky	Ueber Furfurölreactionen. (Sept.)	'Zeitschr. f. Physiol. Chem.' xii. 355–376, 377–395, xiii. 248–263; 'Ber.' xxii. [Ref.], 600–602 (Abs.)
K. Katayama	Ueber eine neue Blutprobe bei der Kohlenoxydvergiftung. (Oct. 2.)	'Archiv f. path. Anat.' cxiv. 53–64; 'Chem. News,' lxi. 241; 'J. Chem. Soc. lvi. 88 (Abs.)
A. Grünwald	Spectralanalyse des Kadmiums. (Read Oct. 11.)	'Sitzungsb. Akad. Wien,' xcvii. [II.], 967–1044; 'Monatshefte f. Chem.' ix. 956–1034; 'Wien. Anz.' 1888, 187 (Abs.); 'Chem. News,' lix. 2–7, 16–19, 29–31; 'J. Chem. Soc.' lvi. 455 (Abs.)
J. C. B. Burbank	Photography of the Least Refrangible Portion of the Solar Spectrum. (Oct.)	'Phil. Mag.' [5], xxvi. 391–393; 'Chem. News,' lviii. 311–312; 'Beiblätter,' xiii. 219 (Abs.)

Chemical Relations, 1888, 1889.

A. Kundt	Photographien, welche die Sensibilisirung photographischer Trockenplatten mittels absorbirender Farbstoffe zeigen. (Read Nov. 2.)	'Verh. phys. Gesellsch. Berl.' vii. 86 (notice); 'Nature,' xxxix. 120 (Abs.)
Grimbert	Sur un nouveau mode de recherche de l'urobiline dans l'urine. (Dec.)	'J. de Pharm.' [5], xviii. 481–482; 'J. Chem. Soc.' lvi. 324 (Abs.)
A. Hansen	Ueber die Bedeutung des Chlorophyllfarbstoffs ('Naturw. Rundschau,' ii. 501–502.)	'Bied. Centr.' 1888, 357–388 (Abs.); 'J. Chem. Soc.' liv. 867–868 (Abs.)
H. Ebert	Die Methode der höher Interferenzen, und ihre Verwendbarkeit für die Zwecke der qualitativen Spectralanalyse. (Habilitationsschrift, Erlangen, 1888.)	'Zeitschr. f. physikal. Chem.' ii. 434 (Abs.)

1889.

H. W. Vogel	Capt. Abney über farbenempfindliche Verfahren. (Jan.)	'Phot. Mittheil.' xxv. 254, 255; 'Beiblätter,' xiii. 383 (Abs.)
W. Crookes	On the Use of the Spectroscope in the Detection and Discrimination of the so-called 'Rare Earths.' (Read Mar. 21.)	'J. Chem. Soc.' lv. 255–285; 'Zeitschr. f. physikal. Chem.' vi. 88 (Abs.); 'Beiblätter,' xiv. 173 (Abs.)
O. Wallach	Ueber die Molecularrefraction des Camphens. (March.)	'Ann. Chem. u. Pharm.' cclii. 136–140; 'J. Chem. Soc.' lvi. 1069 (Abs.) 'Ber.' xxii. (Ref.), 585 (Abs.)
T. Pelham Dale	On a Relation existing between the Density and Refraction of Gaseous Elements, and also of some of their Compounds. (Read May 25.)	'Proc. Phys. Soc.' x. 189–193.
S. Handler	Ueber die Reduction des Hämoglobins im Herzen. (May.)	'Zeitschr. f. Biol.' xxvi. 233–258; 'J. Chem. Soc.' lvi. 1225 (Abs.)
Ph. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques. (Read June 17.)	'C. R.' cviii. 1249–1251; 'J. Chem. Soc.' lvi. 805 (Abs.); 'Beiblätter,' xiii. 669 (Abs.)
A. Babés	Note sur quelques matières colorantes et aromatiques produites par le bacille pyocyanique. (Read June 22.)	'C. R. de la Soc. biol.' (Paris) [9], i. 438–440; 'J. Chem. Soc.' lviii. 189–190 (Abs.)
A. Letellier	Recherches sur la pourpre produite par le *Purpura lapillus*. (Read July 8.)	'C. R.' cviii. 82–85; 'J. Chem. Soc.' lvi. 1207–1208 (Abs.)
G. Krüss and H. Moraht.	Zur spectrocolorimetrischen Eisen- bezw. Rhodan-Bestimmung. (Read Aug. 6.)	'Ber.' xxii. 2054–2060; 'J. Chem. Soc.' lvi. 1247–1248 (Abs.)

CHEMICAL RELATIONS, 1889.

M. Althausse and G. Krüss.	Beziehungen zwischen Zusammensetzung und Absorptionsspectrum organischer Verbindungen. (Read Aug. 6.)	'Ber.' xxii. 2065–2070; 'J. Chem. Soc.' lvi. 1093–1094 (Abs.); 'Chem. News,' lx. 240–241 (Abs.); lxi. 209 (Abs.); 'Beiblätter,' xiii. 945–946 (Abs.); 'Zeitschr. f. physikal. Chem.' iv. 585 (Abs.)
T. Costa . .	Sulle correlazioni tra il potere rifrangente ed il potere dispersivo dei derivati aromatici a catene laterali sature. (Aug.)	'Gazz. chim. ital.' xix. 478–498; 'Ber.' xxii. (Ref.), 738 (Abs.); 'Beiblätter,' xiii. 937–939 (Abs.)
C. Timiriazeff .	La protophylline dans les plantes étiolées. (Read Sept. 2.)	'C. R.' cix. 414–416; 'J. Chem. Soc.' lvi. 1236–1237 (Abs.)
A. Grünwald . .	Spectralanalytischer Nachweis von Spuren eines neuen, der eilften Reihe der Mendelejeff'schen Tafel angehörigen Elementes, welches besonders im Tellur und Antimon ausserdem aber auch im Kupfer vorkommt. (Read Oct. 10.)	'Sitzungsb. Akad. Wien,' xcviii. II.*b*, 785–817; 'Chem. News,' lxi. 39 (Abs.); 'Monatsh. f. Chem.' x. 829–861; 'J. Chem. Soc.' lviii. 434–435 (Abs.); 'Beiblätter,' xiv. 278–279 Abs.)
E. H. Amagat and F. Jean.	Sur l'analyse optique des huiles et du beurre. (Read Oct. 14.)	'C. R.' cix. 616–617; 'Mon.Scientifique' (Quesneville) [4], iii. 1396–1397; 'Chem. News,' lxi. 25 (Abs.); 'Ber.' xxii. (Ref.), 777 (Abs.)
K. Scubert . .	Einige physikalische Constanten von Halogensubstitutionsproducten des Benzols und Toluols. (Read Oct. 14.)	'Ber.' xxii. 2519–2524.
J. F. Eykman .	Ueber das ätherische Oel der Betelblätter. (Oct. 20. Read Oct. 28.)	'Ber.' xxii. 2736–2754.
J. H. Gladstone and W. H. Perkin.	On the Correspondence between the Magnetic Rotation and the Refraction and Dispersion of Light by Compounds containing Nitrogen. (Read Nov. 7.)	'J. Chem. Soc.' lv. 750–759.
K. Ångström . .	Études des spectres infra-rouges de l'acide carbonique et de l'oxyde de carbone. (Read Nov. 13.)	'Öfvers. af K. Vet. Akad. Förhandl.' (Stockholm), 1889, No. 9, 549–557.
A. Bettendorff .	Studien über die Erden der Cerium- und Yttrium-Gruppe. (Received Nov. 14.)	'Ann. Chem. u. Pharm' cclvi. 159–170.
K. Neumann and H. Rey.	Ueber Farbstoffe aus der Gruppe der Benzeine. (Recd. Nov. 14.)	'Ber.' xxii. 3001–3004; 'Beiblätter,' xiv. 281 (Abs.)
L. Macchiati . .	Die Farbstoffe der Zapfen von *Abies excelsa*. (Nov.)	'Naturw. Rundschau,' iv. 608; 'Chem. Centr.' [4], ii. Bd. i. 164 (Abs.); 'J. Chem. Soc.' lviii. pt. i. 641–642 (Abs.)

CHEMICAL RELATIONS, 1889, 1890.

M. Le Blanc	Optisch.-chemische Studien mit Berücksichtigung der Dissociationtheorie. (Nov.)	'Zeitschr. f. physikal. Chem.' iv. 553–560; 'J. Chem. Soc.' lviii. 213 (Abs.); 'Beiblätter,' xiv. 272 (Abs.)
J. F. Eykman	Zur Constitution des Asarons. (Read Dec. 9.)	'Ber.' xxii. 3172–3176.
W. de W. Abney and G. S. Edwards.	On the Effect of the Spectrum on the Haloid Salts of Silver. (Recd. Nov. 26. Read Dec. 12.)	'Proc. Roy. Soc.' xlvii. 249–275; 'J. Chem. Soc.' lviii. 933 (Abs.); 'Beiblätter,' xiv. 791 (Abs.)
C. Bender	Brechungsexponenten normaler Salzlösungen. (Dec.)	'Ann. Phys. u. Chem.' [N.F.], xxxix. 89–96; 'J. Chem. Soc.' lviii. 549 (Abs.)
R. Heise	Zur Kenntniss des Rothweinfarbstoffes. (Arbeiten aus dem kaiserlichen Reichsgesundheitsamte, Sonderabdruck.)	'Ber.' xxii. (Ref.), 823 (Abs.)
F. Flavitsky	Dextro-rotatory Terpenes from *Pinus cembra*. (In Russian.)	'J. Russ. Phys.-Chem. Soc.' xxi. 367–375; 'J. Chem. Soc.' lviii. 789–790 (Abs.)
H. Kayser and C. Runge.	Ueber die Spectren der Elemente ('Abhandl. Akad. Berlin,' 1889, 93 pp.)	'Beiblätter,' xii. 87 (title).
W. Kouriloff	Terpenes from the Oil of *Pinus abies*. (In Russian.)	'J. Russ. Phys.-Chem. Soc.' xxi. 357–367; 'J. Chem. Soc.' lviii. 789 (Abs.)

1890.

R. Wegner	Ueber die Molekularrefraktion der Haloidsalze des Lithiums, Natriums und Kaliums. (Jan. 8.)	'Chem. Centr.' 1890, 78–79; 'J. Chem. Soc.' lviii. 549 (Abs.)
A. P. Laurie	Madder Lakes. (Jan. 24)	'Chem. News,' lxi. 60–61.
H. Gautier and G. Charpy.	Sur l'état de l'iode en dissolution. (Read Jan. 27.)	'C. R.' cx. 189–191; 'Chem. News,' lxi. 97 (Abs.); 'Ber.' xxiii. (Ref.), 135 (Abs.)
F. Schütt	Ueber Peridineenfarbstoffe. (Jan.)	'Ber. deutsch. bot. Gesellsch.' viii. 9–32; 'Chem. Centr.' [4], ii. 767–768 (Abs.); 'J. Chem. Soc.' lviii. 1172–1173 (Abs.)
H. Moissan	Action du fluor sur les différentes variétés de carbone. (Read Feb. 10.)	'C. R.' cx. 276–279; 'Chem. News,' lxi. 120 (Abs.)
A. B. Griffiths	Sur une nouvelle ptomaïne de putréfaction, obtenue par la culture du Bacterium Allii. (Read Feb. 24.)	'C. R.' cx. 416–418; 'Chem. News,' lxi. 145 (Abs.)
G. Salet	Sur la flamme bleue du sel marin, et sur la réaction spectroscopique du chlorure de cuivre. (Feb.)	'Bull. Soc. chim. franç.' [3], iii. 328–329; 'Chem. News,' lxi. 377 (Abs.)

CHEMICAL RELATIONS, 1890.

C. A. Bischoff and P. Walden.	Ueber die physikalischen Constanten der substituirten Aethenyltricarbonsäureester. (Recd. Feb. 27. Read March 10.)	'Ber.' xxiii. 660–664; 'J. Chem. Soc.' lviii. 745–746 (Abs.)
J. F. Eykman	Ueber die Umwandlung von Allyl in Propenylbenzolderivate, ihre Dispersion und Refraction. (Read March 24.)	'Ber.' xxiii. 855–864; 'J. Chem. Soc.' lviii. 748–749 (Abs.); 'Beiblätter,' xiv. 502–505 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 91 (Abs.)
T. Araki	Ueber den Blutfarbstoff und seine näheren Umwandlungsproducte. (March.)	'Zeitschr. f. physiol. Chem.' xiv. 405–415; 'J. Chem. Soc.' lviii. 1012–1013 (Abs.)
F. Kehrmann	Einiges über Beziehungen zwischen Färbung und chemischer Constitution. (April 16.)	'Chem. Zeit.' xiv. 508, 527, 541–542; 'Beiblätter,' xiv. 618 (Abs.)
T. E. Thorpe and A. E. Tutton.	Phosphorous Oxide. Part I. (Read April 17.)	'J. Chem. Soc.' lvii. 545–573.
C. Liebermann and F. Haber.	Ueber Bidioxymethylenindigo. (Recd. May 24.)	'Ber.' xxiii. 1566–1567; 'J. Chem. Soc.' lviii. 1140 (Abs.)
Ph. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques (alcoöls de la série grasse). (Read May 27.)	'C. R.' cx. 1071–1074; 'Zeitschr. f. physikal. Chem.' vi. 374 (Abs.)
T. Costa	Sul peso molecolare e sul potere rifrangente del cloruro di zolfo. (June 1.)	'Gazz. chim. ital.' xx. 367–372.
A. Percy Smith	The Violet Flame produced by Common Salt in a Coal Fire. (June.)	'Chem. News,' lxi. 292–293; 'J. Chem. Soc.' lviii. 1202 (Abs.)
R. Löwenherz	Ueber die Molecularrefraction der Nitrate. (Read July 14.)	'Ber.' xxiii. 2180–2182; 'Zeitschr. f. physikal. Chem.' vi. 382 (Abs.)
Ph. Barbier and L. Roux.	Recherches sur la dispersion dans les composés organiques (éthers-oxydes.) (Read July 21.)	'C. R.' cxi. 180–183; 'Zeitschr. f. physikal. Chem.' vi. 377 (Abs.); 'Bull. Soc. Chim.' [3], iv. 9–16; 'Chem. News,' lxii. 249 (Abs.)
" "	Recherches sur la dispersion dans les composés organiques (acides gras). (Read July 28.)	'C. R.' cxi. 235–236; 'Zeitschr. f. physikal. Chem.' vi. 378 (Abs.); 'Bull. Soc. Chim.' [3], iv. 614–622; 'Chem. News,' lxii. 249 (Abs.)
C. Bohr	Sur les combinaisons de l'hémoglobine avec l'oxygène. (Read July 21.)	'C. R.' cxi. 195–197; 'Chem. News,' lxii. 74 (Abs.)
E. Laurent	Réduction des nitrates par la lumière solaire (première note). (Aug.)	'Bull. Acad. Belg.' xx. 303–308.

CHEMICAL RELATIONS, 1890, 1891.

Lecoq de Boisbaudran.	Nouvelles recherches sur la gadoline de M. de Marignac. (Read Sept. 8.)	'C. R.' cxi. 393–395; 'Nature,' xlii. 512 (Abs.); 'Chem. News,' lxii. 178 (Abs.)
J. H. Gladstone and G. Gladstone.	The Refraction and Dispersion of Fluor-Benzene and Allied Compounds. (Sept.)	'Phil. Mag.' [5], xxxi. 1–9; 'Zeitschr. f. physikal. Chem.' vii. 331 (Abs.)
R. Nasini and T. Costa.	Sopra un caso singolare nella rifrazione dei composti organici. (Read Oct. 19.)	'Rend. R. Accad. d. Lincei' [4], vi. 259–263; 'Phil. Mag.' [5], xxxi. 448 (Abs.)
J. H. Gladstone .	Molecular Dispersion. (Dec. 27, 1890.)	'Nature,' xliii. 198.
R. Löwenherz .	Ueber die Molecularrefraction stickstoffenthaltender Substanzen. (Dec.)	'Zeitschr. f. physikal. Chem.' vi. 532–563.
E. Demarçay . .	Les terres rares	'Rev. générale des Sciences pures et appliquées,' 1890, No. 13, 396–402; 'Chem. News,' lxii. 85 (Abs.)
C. Pulfrich . .	Das Totalreflectometer und das Refractometer für Chemiker, ihre Anwendung in der Krystalloptik und zur Untersuchung der Lichtbrechung von Flüssigkeiten. (Leipzig, W. Engelmann, 1890.)	'Nature,' xliv. 538 (notice).
S. Handler . .	Ueber die Reduction des Hämoglobin im Herzen.	'Zeitschr. f. Biol.' xxvi. 233–258; 'J. Chem. Soc.' lvi. 1225 (Abs.)

1891.

A. Bettendorff .	Studien über die Erden des Cerium- und Yttrium-Gruppe. (Jan.)	'Ann. Chem. u. Pharm.' cclxiii. 164–174; 'Chem. News,' lxiii. 159–160, 172–173.
J. W. Brühl . .	Ueber die Beziehungen zwischen der Refraction der Gase und Dämpfe und deren chemischen Zusammensetzung. (Jan.)	'Zeitschr. f. physikal. Chem.' vii. 1–33.
V. Schumann. .	On Determining the Sensitiveness of Photographic Plates by means of the Spectrograph. (Jan.)	'Chem. News,' lxiii. 33–34.
E. Becquerel. .	Observations sur la communication de M. Lippmann au sujet de la reproduction photographique des couleurs. (Read Feb. 2.)	'C. R.' cxii. 275–277; 'Chem. News,' lxiii. 111 (Abs.)
H. Kayser and C. Runge. .	Ueber die Spectra der Elemente der zweiten Mendeléjeff'schen Gruppe. (Read Feb. 19.)	'Ann. Phys. u. Chem.' [N.F.] xliii. 385–409; 'Sitzungsb. Akad. Berl.' 1891, I. 177–178 (Abs.); 'Zeitschr. f. physikal. Chem.' viii. 575 (Abs.)

CHEMICAL RELATIONS, 1891.

B. Walter	Ueber das α-Monobromnaphthalin. (Feb.)	'Ann. Phys. u. Chem.' [N.F.], xlii. 511–512; 'Phil. Mag.' [5], xxxi. 367.
M. Schütze	Ueber den Zusammenhang zwischen Farbe und Constitution der Verbindungen. (Feb.)	'Zeitschr. f. physikal. Chem.' ix. 109–136; 'Beiblätter,' xvi. 428–429 (Abs.)
V. Schumann	Photochemical Researches. (Feb.)	'Chem. News,' lxiii. 97.
J. W. Brühl	Ueber die Beziehungen zwischen die spectrometrischen Constanten und der chemischen Constitution des Epichlorhydrin, des Acet- und Paraldehyds und des Benzols. (Feb.)	'Ber.' xxiv. 656–658; 'Zeitschr. f. physikal. Chem.' vii. 521 (Abs.)
Ph. Barbier and L. Roux.	Recherches sur la dispersion des composés organiques (éthers). (Read Mar. 16.)	'C. R.' cxii. 582–584; 'Zeitschr. f. physikal. Chem.' viii. 144 (Abs.)
E. Laurent	Réduction des nitrates par la lumière solaire (deuxième note). (March.)	'Bull. Acad. Belg.' [3], xxi. 337–345; 'Nature,' xliv. 24 (Abs.)
B. Brauner	Ueber das Atomgewicht des Lanthans. (Recd. April 25.)	'Ber.' xxiv. 1328–1331; 'Chem. News,' lxiv. 50 (Abs.)
G. Krüss	Beiträge zur Chemie des Erbiums und Didyms. (I.) (April.)	'Ann. Chem. u. Pharm.' cclxv. 1–27; 'Chem. News,' lxiv. 65–66, 75–76, 99–101, 120–121.
H. O. G. Ellinger	Optische Bestimmung der Albuminmenge im Harn. (May.)	'J. prakt. Chem.' xliv. 256; 'Chem. News,' lxiv. 262 (Abs.)
W. H. Perkin	The Refractive Power of certain Organic Compounds at Various Temperatures. (Read June 18.)	'J. Chem. Soc.' lxi. 287–310; 'Beiblätter,' xvii. 559–561 (Abs.)
E. Schunck	Contributions to the Chemistry of Chlorophyll. No. IV. (Recd. June 16. Read June 18.)	'Proc. Roy. Soc.' l. 302–317; 'J. Chem. Soc.' lxiv. I. 41–42 (Abs.)
E. E. Brooks	On Terminal Spectra observed in Vacuo. (July.)	'Chem. News,' lxiv. 30–31.
W. Böhlendorff	Bemerkung zu der Abhandlung des Herrn B. Walter 'Ueber den Nachweis des Zerfalles von Moleculargruppen in Lösungen durch Fluorescenz und Absorptionserscheinungen.' (July.)	'Ann. Phys. u. Chem.' [N.F.], xliii. 784–789.
C. M. Thompson	On Didymium from Different Sources. (Aug.)	'Brit. Assoc. Report,' 1891, 511; 'Chem. News,' lxiv. 167.
F. A. Gooch and T. S. Hart.	The Detection and Determination of Potassium Spectroscopically. (Aug.)	'Amer. J. Sci.' [3], xlii. 448–459; 'Chem. News,' lxv. 22–24, 32–34; 'Nature,' xlv. 212 (Abs.)

CHEMICAL RELATIONS, 1891, 1892.

T. Costa	Sul potere rifrangente moleculare delle carbilamine et dei nitrili. (Read Nov. 15.)	'Rend. R. Accad. d. Lincei' [4], vii. 308–313; 'Rivista scient. industr.' xxiv. 104–109.
O. Knoblauch	Absorptions-Spectralanalyse sehr verdünnter Lösungen.	'Ann. Phys. u. Chem.' [N.F.]. xliii. 738–783; 'Chem. News,' lxiv. 120 (Abs.)
R. E. Schmidt and L. Gattermann.	Ueber Oxyderivative des Alizarin-Blau.	'J. prakt. Chem.' xliv. 103–109; 'Chem. News,' lxiv. 261 (Abs.)

1892.

F. Müller	Ueber das ätherische Oel der Lorbeer-Beeren. (Read Feb. 11.)	'Ber.' xxv. 547–551; 'Beiblätter,' xvi. 605 (Abs.)
A. Weigle	Spectrophotometrische Untersuchungen der Salze aromatischer Basen. (Feb.)	'Zeitschr. f. physikal. Chem.' xi. 227–247, 426–428; 'Beiblätter,' xvii. 506 (Abs.)
Lecoq de Boisdaudran.	Recherches sur le samarium. (Read March 14.)	'C. R.' cxiv. 572–577.
R. Bach	Thermochemie des Hydrazins, nebst einer Bemerkung über die Molecularrefraction einiger Stickstoffverbindungen. (April.)	'Zeitschr. f. physikal. Chem.' ix. 241–263; 'Beiblätter,' xvi. 515–517 (Abs.)
A. Bettendorff	Studien über die Erden der Cerium- und Yttrium-Gruppe. (June.)	'Ann. der Chem.' cclxx. 376–383; 'Ber.' xxv. (Ref.), 765 (Abs.); 'Chem. News,' lxvi. 307, 320–321 (Abs.); 'J. Chem. Soc.' lxii. 1400–1401 (Abs.); 'Beiblätter,' xvi. 744–745 (Abs.)
J. W. Brühl	Ueber das Trimethylen. (Read June 11.)	'Ber.' xxv. 1952–1956; 'Beiblätter,' xvii. 823 (Abs.)
G. Carrara	Sul peso molecolare e sul potere rifrangente dell' acqua ossigenata. (Read July 3.)	'Rend. R. Accad. Roma,' [5], i. II. sem. 19–24; 'Gazz. chim. ital.' xxii. II. 341–349; 'J. Chem. Soc.' lxiv. II. 163 (Abs.)
G. Krüss and H. Moraht.	Ueber die Reaction zwischen Ferrisalzen und löslichen Rhodaniden. (July.)	'Zeitschr. f. anorg. Chem.' i. 399–404; 'Ber.' xxv. (Ref.), 917 (Abs.); 'Chem. News,' lxvi. 198 (Abs.)
H. Landolt and Hans Jahn.	Ueber die Molecularrefraction einiger einfachen organischen Verbindungen für Wellen von unendlich grosser Wellenlänge. (Sept.)	'Zeitschr. f. physikal. Chem.' x. 289–320; 'Beiblätter,' xvii. 329–331 (Abs.)
G. Krüss and H. Krüss.	Beiträge zur quantitativen Spectralanalyse. (Sept.)	'Zeitschr. f. anorg. Chem.' i. 104–125; 'Zeitschr. f. physikal. Chem.' x. 432 (Abs.); 'Beiblätter,' xvi. 606 (Abs.); 'Zeitschr. f. anal. Chem.' xxxii. 574 (Abs.); 'J. Chem. Soc.' lxiv. II. 283–284 (Abs.)

CHEMICAL RELATIONS, 1892, 1893.

J. M. Eder	Beiträge zur Spectralanalyse. (Read Nov. 3.)	'Denkschr. Akad. Wien,' lx. 1–24.
V. Markovnikoff and A. Reformatsky.	Bulgarian (Turkish) Oil of Roses. (Read Nov. 5, O.S.) (In Russian.)	'J. Russ. Phys. Chem. Soc.' xxiv. 663–686; 'J. Chem. Soc.' lxiv. I. 662–663 (Abs.)
F. A. Gooch and J. J. Phinney.	Quantitative Determination of Rubidium by the Spectroscope. (Nov.)	'Amer. J. Sci.' xliv. 392–400; 'Nature,' xlvii. 94 (Abs.)
F. Zecchini	Sul potere rifrangente del fosforo. I. Potere rifrangente del fosforo libro e delle sue combinazioni cogli elementi o gruppi monovalenti. (Read Dec. 6.)	'Gazz. chim. ital.' xxiii. I. 97–120; 'J. Chem. Soc.' lxiv. II. 353–354 (Abs.)
C. Féry	Sur l'étude des réactions chimiques dans une masse liquide par l'indice de réfraction. (Read Dec. 26.)	'C. R.' cxv. 1309–1312; 'J. Chem. Soc.' lxiv. II. 201 (Abs.)
C. Graebe	Ueber Azofarbenspectra. (Dec.)	'Zeitschr. f. physikal. Chem.' x. 673–698; 'Beiblätter,' xvii. 336 (Abs.)
C. A. Lobry de Bruijn.	L'hydroxylamine	'Rec. trav. chim. des Pays-Bas,' xi. 18–50; 'Ber.' xxv. (Ref.), 684–685 (Abs.)
A. Görtz	Ueber spectrophotometrische Affinitätsbestimmungen. (Dissertation, Tübingen, 1892, 57 pp.)	'Beiblätter,' xvii. 378 (Abs.)
W. Ostwald	Ueber die Farbe der Ionen	'Abhandl. math. phys. Klasse Sächs. Gesellsch. d. Wiss.' xviii. No. II. 281–307; 'Beiblätter,' xvi. 534–537 (Abs.)
J. Janeček	Gerichtlich-chemischer Nachweis von Blut.	'Zeitschr. f. anal. Chem.' xxxi. 236–237 (Abs.); 'Chem. News,' lxvi. 32 (Abs.)

1893.

P. Bary	Sur la composition des solutions aqueuses des sels d'après les indices de réfraction. (Read Jan. 8.)	'C. R.' cxviii. 71–73; 'J. Chem. Soc.' lxvi. II. 132 (Abs.)
G. Krüss and A. Loose.	Verhalten der Gadoliniterden gegen Kaliumchromat. (Jan.)	'Zeitschr. f. anorg. Chem.' iii. 92–107; 'Chem. News,' lxvii. 75–76, 87–89, 100.
H. Bertin-Sans and J. Moitessier.	Oxyhématin, hématin réduit, et hémochromogène. (Read Feb. 20.)	'C. R.' cxvi. 401–403; 'Bull. Soc. Chim.' [3], ix. 380–382; 'Ber.' xxvi. (Ref.), 247 (Abs.); 'Chem. News,' lxviii. 26 (Abs.); 'J. Chem. Soc.' lxiv. I. 447–448 (Abs.)

CHEMICAL RELATIONS, 1893.

R. Braunschweig .	Ueber die Ester der Methylbernsteinsaüre (Brenzweinsäure). (Feb.)	'J. prakt. Chem.' [N.F.], xlvii. 274–300.
H. Bertin-Sans and J. Moitessier.	Nouveau procédé pour obtenir de l'oxyhémoglobine à l'aide d'oxyhématine et d'une matière albuminoïde. (Read Mar. 10.)	'Bull. Soc. Chim.' [3], ix. 243–244; 'Chem. News,' lxvii. 301 (Abs.)
" "	Action de l'oxyde de carbone sur l'hématine réduite et sur l'hémochromogène. (Read Mar. 13.)	'C. R.' cxvi. 591–592; 'Ber.' xxvi. (Ref.), 292–293 (Abs.); 'J. Chem. Soc.' lxiv. I. 448 (Abs.)
Lecoq de Boisbaudran.	Recherches sur le samarium. (Read Mar. 20.)	'C. R.' cxvi. 611–613; 'Chem. News,' lxvii. 180 (Abs.)
" "	Recherches sur le samarium. (Read Mar. 27.)	'C. R.' cxvi. 674–677; 'Chem. News,' lxvii. 258–259 (Abs.)
L. Meyer . .	Nachtrag zu der Abhandlung von A. Weigle, 'Spectrophotometrische Untersuchung der Salze aromatischer Basen.' (March.)	'Zeitschr. f. physikal. Chem.' xi. 426–428; 'J. Chem. Soc.' lxiv. II. 464 (Abs.)
G. Krüss . .	Ueber die Erbinerde. (March) .	'Zeitschr. f. anorg. Chem.' iii. 353–369; 'Chem. News,' lxviii. 148–149, 158–159, 165–166, 176–178, 194, 209, 217–218; J. Chem. Soc. lxiv. II. 376 (Abs.)
K. Hofmann and G. Krüss.	Ueber die Holminerde. (April) .	'Zeitschr. f. anorg. Chem.' iii. 407–414; 'Ber.' xxvi. (Ref.), 473–474 (Abs.)
H. Bertin-Sans and J. Moitessier.	Action de l'oxyde de carbone sur l'hématine réduite et sur l'hémochromogène. (Read May 12.)	'Bull. Soc. Chim.' [3], ix. 382–384; 'Chem. News,' lxviii. 26 (Abs.)
K. Hofmann and G. Krüss.	Ueber die Terbinerde. (May) .	'Zeitschr. f. anorg. Chem.' iv. 27–43; 'Ber.' xxvi. (Ref.), 474–475 (Abs.)
C. Trapesonzjanz .	Ueber die Molecularrefraction stickstoffenthaltenden Substanzen. (Read June 8.)	'Ber.' xxvi. 1428–1433; 'J. Chem. Soc.' lxiv. II. 401 (Abs.)
J. M. Eder and E. Valente.	Ueber den Verlauf der Bunsen'schen Flammereaction im ultravioletten Spectrum. (Read July 6.)	'Denkschr. Akad. Wien,' lx. 467–476.
E. Demarçay . .	Sur la simplicité du samarium. (Read July 17.)	'C. R.' cxvii. 163–164; 'J. Chem. Soc.' lxiv. II. 526 (Abs.); 'Chem. News,' lxviii. 73–74 (Abs.)
Lecoq de Boisbaudran.	Recherches sur le samarium. (Read July 24.)	'C. R.' cxvii. 199–201; 'Beiblätter,' xviii. 452–453 (Abs.); 'J. Chem. Soc.' lxiv. II. 526–527 (Abs.); 'Chem. News,' lxviii. 313 (Abs.)

H. Bertin-Sans and J. Moitessier.	Méthode pour démontrer rapidement le déplacement par l'oxygène de l'oxyde de carbone de la carboxyhémoglobine. (Read July 28.)	'Bull. Soc. Chim.' [3], ix. 722; 'Chem. News,' lxviii. 221 (Abs.)
O. Wallach . .	Zur Kenntniss der Terpene und der ätherischen Oele. (26ste Abhandl.) (Aug.)	'Ann. d. Chem. u. Pharm.' cclxxvii. 105–154; 'Ber.' xxvi. (Ref.), 869–871 (Abs.); 'J. Chem. Soc.' lxvi. I. 43–45 (Abs.)
„	Zur Kenntniss der Terpene und der ätherischen Oele. (27ste Abhandl.) (Aug.)	'Ann. d. Chem. u. Pharm.' cclxxvii. 154–161; 'Ber.' xxvi. (Ref.), 871–872 (Abs.); 'J. Chem. Soc.' lxvi. I. 46 (Abs.)
S. J. Ferreira da Silva.	Sur une nouvelle réaction de l'ésérine et une matière colorante verte dérivée du même alcaloïde. (Read Aug. 14.)	'C. R.' cxvii. 330–331; 'Bull. Soc. Chim.' [3], ix. 753–754; 'J. Chem. Soc.' lxiv. I. 741 (Abs.); 'Chem. News,' lxviii. 221 (Abs.)
F. Smith . .	Note on the Nature of the Dandruff and its Pigment from the Skin of the Horse. (Sept.)	'J. Physiol.' xv. 162–166; 'J. Chem. Soc.' lxiv. II. 585–586 (Abs.)
E. Demarçay . .	L'analyse qualitative et la spectroscopie. (Dec.)	'Rev. générale des sciences,' iv. 725–729.
K. Hofmann and G. Krüss.	Ueber die Holminerde . . .	'Zeitschr. f. anorg. Chem.' iii. 407–414; 'J. Chem. Soc.' lxiv. II. 466–467 (Abs.); 'Beiblätter,' xvii. 688 (Abs.)

IX.

THEORETICAL PAPERS.

1882.

M. Weinberg . .	Interferenzstreifen im prismatischen und im Beugungsspectrum ('Ber. d. naturwiss. Ver. d. techn. Hochsch. in Wien,' 1882, 1–8).	'Carl. Repert.' xviii. 600–608; 'Beiblätter,' vi. 746 (Abs.)

1885.

R. von Kövesligethy	Theorie der continuirlichen Spectra. (Read Oct. 19.)	'Math. u. naturw. Ber. aus Ungarn,' iv. 9–10; 'Beiblätter,' xii. 346–348 (Abs.)

1886.

E. Lommel	Die Beugungserscheinungen geradlinig begrenzter Schirme. (Read May 1.)	'Abhandl. k. bayer. Akad.' [2], xv. 529–664; 'Sitzungsb. Akad. München,' xvi. 84–87 (Abs.) 'Beiblätter,' xi. 42–46 (Abs.)

THEORETICAL PAPERS, 1887.

1887.

R. von Kövesligethy	Theorie der discontinuirlichen Spectra. (Read May 16.)	'Math. u. naturw. Ber. aus Ungarn,' v. 20–28; 'Beiblätter,' xii. 346–348 (Abs.)
W. Michelson .	Theoretical Essay on the Distribution of Energy in the Spectra of Solids. (May.) (In Russian.)	'J. Russ. Phys.-Chem. Soc.' xix. IV. 79–99; 'J. de Phys.' vi. 467–479 (Abs.); 'Phil. Mag.' [5], xxv. 425–435 (Abs.)
K. Klar . . .	Die Theorie des Glühens. (May.)	'Centralzeit. f. Opt. u. Mech.' viii. 109–111; 'Beiblätter,' xi. 777 (Abs.)
R. von Kövesligethy	Theorie der Lockyer'schen Spectralmethode und Linienverwandschaften. (Read June 20.)	'Math. u. naturw. Ber. aus Ungarn,' v. 29–31; 'Beiblätter,' xii. 579–580 (Abs.)
A. Grünwald . .	Ueber die merkwürdigen Beziehungen zwischen dem Spektrum des Wasserdampfes und den Linienspektrum des Wassertoffs und Sauerstoffs, sowie über die chemische Struktur der beiden letztern, und ihre Dissociation in der Sonnenatmosphäre. (July 17.)	'Astr. Nachr.' cxvii. 199–214; 'Phil. Mag.' [5], xxiv. 354–367; 'Chem. News,' lvi. 186–188, 201–202, 223–224, 232; 'J. Chem. Soc.' lii. 1070–1071 (Abs.); 'Nature,' xxxvi. 501–502 (Abs.); 'Am. J.' [3], xxxix. 399 (Abs.); 'Beiblätter,' xii. 245–246 (Abs.); 'Zeitschr. f. physikal. Chem.' ii. 88 (Abs.)
R. von Kövesligethy	Mathematische Spectralanalyse (Aug.)	'Astr. Nachr.' cxvii. 328–338; 'Beiblätter,' xii. 346–348 (Abs.)
A. E. Nordenskiöld	Sur un rapport simple entre les longueurs d'onde des spectres. (Read Nov. 21.)	'C. R.' cv. 988–995; 'Zeitschr. f. physikal. Chem.' ii. 245 (Abs.)
E. F. J. Love . .	On a Method for Discriminating Real from Accidental Coincidences between the Lines of Different Spectra, with some Applications. (Read Nov. 26.)	'Phil. Mag.' [5], xxv. 1–6; 'Zeitschr. f. physikal. Chem.' ii. 447 (Abs.)
A. Grünwald . .	Mathematische Spectralanalyse des Magnesiums und der Kohle. (Read Dec. 1.)	'Sitzungsb. Akad. Wien,' xcvi. II. 1154–1216; 'Monatsh. f. Chem.' viii. 650–712; 'Phil. Mag.' [5], xxv. 343–350 (Abs.); 'Beiblätter,' xii. 661–662 (Abs.); 'Zeitschr. f. physikal. Chem.' ii. 256 (Abs.)
R. von Kövesligethy	W. Michelson's Spectraltheorie. (Read Dec. 12.)	'Math. naturwiss. Ber. aus Ungarn,' vii. 24–35; 'Beiblätter,' xiv. 116–117.

THEORETICAL PAPERS, 1888, 1889.

1888.

C. Fiévez . .	De la constitution optique des raies spectrales, en rapport avec la théorie ondulatoire de la lumière (Presented May 8.)	'Bull. Acad. Belg.' [3]. xv. 694 (title); 'Nature,' xxxviii. 511 (Abs.)
J. Willard Gibbs .	A Comparison of the Elastic and Electrical Theories of Light with respect to the Law of Double Refraction and the Dispersion of Colours. (June.)	'Amer. J. Sci.' [3], xxxv. 467–475.
C. Runge . .	On the Harmonic Series of Lines in the Spectra of the Elements. (Sept.)	'Brit. Assoc. Rep.' 1888, 576–577; 'Beiblätter,' xiv. 509–510 (Abs.)
A. Grünwald . .	Spectralanalyse des Kadmiums. (Read Oct. 11.)	'Sitzungsb. Akad. Wien,' xcvii. II. 967.
E. Wilson . .	The Law of Dispersion. (Oct.) .	'Phil. Mag.' [5], xxvi. 385–389; 'Zeitschr. f. physikal. Chem.' ii. 973 (Abs.)
T. P. Dale . .	On the Upper Limit of Refraction in Selenium and Bromine. (Nov.)	'Proc. Phys. Soc.' x. 17–23; 'Phil. Mag.' [5], xxvii. 50–56.

1889.

J. S. Ames . .	Grünwald's Mathematical Spectrum Analysis. (Feb.)	'Amer. Chem. J.' xi. 138–141; 'Nature,' xl. 18; 'Beiblätter,' xiii. 941–942 (Abs.)
„ . .	The Concave Grating in Theory and Practice. (March 27.)	'Phil. Mag.' [5], xxvii. 369–384; 'Beiblätter,' xiii. 673 (Abs.)
E. Conrady . .	Berechnung der Atomrefraction für Natriumlicht. (March.)	'Zeitschr. f. physikal. Chem.' iii. 210–227.
W. Michelson .	Modern Researches on the Theory of Continuous Spectra. (April.)	'J. Russ. Phys.-Chem. Soc.' xxi. 87–103; 'Beiblätter,' xiv. 277–278 (Abs.)
T. P. Dale . .	On a Relation existing between the Density and Refraction of Gaseous Elements, and also of some of their Compounds. (Read May 25.)	'Phil. Mag.' [5], xxviii. 268–272.
A. Grünwald . .	Spectralanalytischer Nachweis von Spuren eines neuen, der eilften Reihe der Mendelejeff'schen Tafel angehörigen Elementes, welches besonders im Tellur und Antimon, ausserdem aber auch im Kupfer vorkommt. (Oct.)	'Sitzungsb. Akad. Wien,' xcviii. II.*b*, 785–817; 'Monatsh. f. Chem.' x. 829–861; 'J. Chem. Soc.' lviii. 434–436 (Abs.); 'Beiblätter,' xiv. 278–279 (Abs.)
M. Koppe . .	Das Minimum der Ablenkung beim Prisma. (Dec.)	'Zeitschr. f. phys. u. chem. Unterricht,' iii. 76–78.

THEORETICAL PAPERS, 1889, 1890.

H. Kayser	Ueber Grünwald's mathematische Spectralanalyse. (Dec.)	'Chem. Zeitung,' xiii. 1655–1687, xiv. 510–511; 'Beiblätter,' xiv. 278 (Abs.)

1890.

R. Nasini	Sullo stato attuale delle teorie riguardanti il potere rifrangente dei composti organici. (Jan. 1.)	'Gazz. chim. ital.' xx. 1–18.
J. R. Rydberg	Sur la constitution des spectres linéaires des éléments chimiques. (Read Feb. 24.)	'C. R.' cx. 394–397; 'Zeitschr. f. physikal. Chem.' v. 222–232; 'Nature,' xli. 431 (Abs.); 'Chem. News,' lxi. 145 (Abs.); 'Beiblätter,' xiv. 507–509 (Abs.)
A. Grünwald	Herr Dr. H. Kayser und meine mathematische Spectralanalyse. (March 8.)	'Chem. Zeitung,' xiv. 325–328; 'Chem. News,' lxi. 159.
H. Deslandres	Propriété fondamentale commune aux deux classes de spectres. Caractères distinctifs de chacune des classes. Variation périodique à trois paramètres. (Read April 8.)	'C. R.' cx. 748–750; 'Nature,' xli. 756 (Abs.); 'Beiblätter,' xiv. 616 (Abs.); 'Zeitschr. f. physikal. Chem.' vi. 87 (Abs.)
A. Grünwald	Ueber das sogenannte zweite oder zusammengesetzte Wasserstoffspectrum von Dr. B. Hasselberg, und die Structur des Wasserstoffs. (Read April 17 and Oct. 9.)	'Anzeiger d. k. Akad. Wien,' xxvi. 70–71, 196–201; 'Monatshefte f. Chem.' xi. 129–130, xiii. 111–145; 'Zeitschr. f. physikal. Chem.' vi. 593 (Abs.); 'Chem. News,' lxii. 288–289, lxiii. 13 (Abs.); 'Beiblätter,' xiv. 779 (Abs.)
J. R. Rydberg	Ueber den Bau der Linienspectren der chemischen Grundstoffe. (April.)	'Zeitschr. f. physikal. Chem.' v. 227–232; 'Phil. Mag.' [5], xxix. 331–337; 'J. Chem. Soc.' lviii. 674–675 (Abs.)
C. Runge	On a Method of Discriminating Real from Accidental Coincidences between the Lines of Different Spectra. (June.)	'Phil. Mag.' [5], xxix. 462–466.
A. W. Gravelaar	Das Minimum der Ablenkung eines Lichtstrahls durch ein homogenes Prisma. (June.)	'Zeitschr. f. phys. u. chem. Unterricht,' iii. 246–247.
Fr. C. G. Müller	Der Satz vom Minimum der Ablenkung beim Prisma. (June.)	'Zeitschr. f. phys. u. chem. Unterricht,' iii. 247–248; 'Beiblätter,' xiv. 979 (Abs.)
J. S. Ames	On the Relations between the Lines of Various Spectra, with special Reference to those of Cadmium and Zinc; and a Re-determination of their Wave-Lengths. (July.)	'Phil. Mag.' [5], xxx. 33–48.

THEORETICAL PAPERS, 1891, 1892.

1891.

G. J. Stoney . .	Analysis of the Spectrum of Sodium, including an Inquiry into the True Place of the Lines that have been regarded as Satellites. (Read March 26 and May 22.)	'Trans. Roy. Soc. Dubl.' [2], iv. 563–608; 'Proc. Roy. Soc. Dubl.' [N.S.], vii. 201–203 (Abs.); 'Phil. Mag.' [5], xxxiii. 503–516 (Abs.); 'Nature,' xliii. 551–552 (Abs.); 'Beiblätter,' xvi. 531–532 (Abs.)
H. Deslandres .	Méthode nouvelle pour la recherche des bandes faibles dans les spectres de bandes. Application aux spectres des hydrocarbons. (Read March 31.)	'C. R.' cxii. 661–663; 'Zeitschr. f. physikal. Chem.' viii. 144 (Abs.)
W. N. Hartley .	On the Relations between the Lines of Various Spectra. (April.)	'Phil. Mag.' [5], xxxi. 359–363.
J. S. Ames . .	On Homologous Spectra. (Sept.)	'Phil. Mag.' [5], xxxii. 319–320.
A. B. Basset . .	On Selective and Metallic Reflexion. (Read Nov. 12.)	'Proc. Math. Soc. London,' xxiii. 4–18; 'Nature,' xlv. 119–121 (Abs.)
G. J. Stoney . .	Analysis of the Spectrum of Sodium, including an Inquiry into the True Place of the Lines that have been regarded as Satellites. (Read Nov. 18.)	'Proc. Roy. Soc. Dubl.' [N.S.], vii. 204–217; 'Nature,' xlv. 166–167 (Abs.)
A. Breuer . .	Uebersichtliche Darstellung der mathematischen Theorien über die Dispersion des Lichtes. I. Theil. (Hannover, Bacmeister, 1890. 50 pp.) II. Theil. Anomale Dispersion. (Erfurt, Bacmeister. 1891. 54 pp.)	'Beiblätter,' xiv. 971 (Abs.); 'Beiblätter,' xvi. 273 (Abs.)

1892.

A. Grünwald . .	Ueber das sogenannte zweite oder zusammengesetzte Wasserstoffspectrum von Dr. B. Hasselberg, und die Structur des Wasserstoffs. I. Theil. Empirisch-Induction-Abtheilung. (Read Feb. 4.)	'Sitzungsb. Akad. Wien,' ci. II. 121–254; 'Monatsh. f. Chem.' xiii. 111–244; 'Zeitschr. f. physikal. Chem.' x. 668 (Abs.); 'Beiblätter,' xvii. 203–204 (Abs.); 'J. Chem. Soc.' lxii. 1351 (Abs.)
D. Goldhammer .	Essay on the Theory of Dispersion and Absorption. (In Russian.) (Feb.)	'J. Russ. Phys.-Chem. Soc.' xxiv. II. 17–39.
R. Nasini . .	Sul potere rifrangente per un raggio di lunghezza d' onda infinita. (March.)	'Gazz. chim. ital.' xxiii. I. 347–354.
G. J. Stoney . .	On the Line Spectra of the Elements. (May.)	'Nature,' xlvi. 29, 126, 222, 268.
C. Runge . .	On the Line Spectra of the Elements. (June.)	'Nature,' xlvi. 100, 200, 247.
E. Ketteler . .	Das Grenzbrechungsexponent für unendlich langen Wellen. Transformation der Dispersionsgleichungen. (Aug.)	'Ann. Phys. u. Chem.' [N.F.], xlvi. 572–583; 'Nature,' xlvi. 484 (Abs.)

THEORETICAL PAPERS, 1892, 1893.

G. J. Stoney . .	Recent Spectroscopic Determinations. (Sept.)	'Nature,' xlvi. 513.

1893.

G. Higgs . .	On the Geometrical Construction of the Oxygen Absorption Lines A, B, and α of the Solar Spectrum. (Read March 9.)	'Proc. Roy. Soc.' liv. 200–208 (Abs.); 'Nature,' xlviii. 164–165 (Abs.); 'Beiblätter,' xviii. 338 (Abs.)
A. Cornu . .	Études sur les réseaux diffringents. Anomalies focales. (Read May 29.)	'C. R.' cxvi. 1215–1222; 'Beiblätter,' xviii. 195–196 (Abs.); 'Nature,' xlviii. 144 (Abs.)
" . .	Sur divers méthodes relatives à l'observation des propriétés appelées anomalies focales des réseaux diffringents. (Read June 19.)	'C. R.' cxvi. 1421–1428; 'Beiblätter,' xviii. 196–198 (Abs.)
A. Kurz . .	Die kleinste Ablenkung im Prisma. (Aug.)	'Zeitschr. f. Math. u. Phys.' xxxviii. (Phys. Abth.), 319–320.
E. Carvallo . .	Le spectre calorifique de la fluorine. (Read Dec. 11.)	'C. R.' cxvii. 845–847; 'Beiblätter,' xviii. 333 (Abs.)

List of the Chief Abbreviations used in the above Catalogue.

Abbreviated Title.	Full Title.
Amer. J. Sci. . . .	American Journal of Science (Silliman's).
Ann. Agron. . . .	Annales Agronomiques.
Ann. Chem. u. Pharm. .	Annalen der Chemie und Pharmacie (Liebig).
Ann. Chim. et Phys. . .	Annales de Chimie et de Physique.
Ann. de Chim. . . .	Annales de Chimie.
Ann. Obs. Bruxelles . .	Annuaire de l'Observatoire de Bruxelles.
Ann. Phys. u. Chem. [N.F.]	Annalen der Physik und Chemie [Neue Folge] (Wiedemann).
Arch. de Genève . .	Archives des Sciences Physiques et Naturelles (Genève).
Arch. f. Anat. u. Physiol. .	Archiv für pathologische Anatomie und Physiologie und für klinische Medicin (Virchow).
Arch. f. d. gesammte Physiol.	Archiv für die gesammte Physiologie (Pflüger).
Arch. f. exper. Pathol. u. Pharmakol.	Archiv für experimentelle Pathologie und Pharmakologie.
Arch. néerland . . .	Archives néerlandaises des Sciences exactes et naturelles (Haarlem).
Astr. Nachr. . . .	Astronomische Nachrichten.
Atti d. R. Accad. d. Lincei	Atti della Reale Accademia dei Lincei.
Beiblätter	Beiblätter zu der Annalen der Physik und Chemie (Wiedemann).
Ber.	Berichte der deutschen chemischen Gesellschaft.
Bied. Centr. . . .	Biedermanns Centralblatt für Agriculturchemie.
Bot. Zeitung . . .	Botanische Zeitung.
Bull. Astron. . . .	Bulletin Astronomique (Observatoire de Paris).
Bull. Soc. Chim. . .	Bulletin de la Société Chimique de Paris.
Bull. Soc. Min. de France	Bulletin de la Société Minéralogique de France.
Chem. Centr. . . .	Chemisches Centralblatt.
C. R.	Comptes Rendus de l'Académie des Sciences (Paris).

List of the Chief Abbreviations—continued.

Abbreviated Title.	Full Title.
Dingl. J.	Dingler's polytechnisches Journal.
Gazz. chim. ital.	Gazzetta chimica italiana.
Göttingen. Nachr.	Nachrichten von der Georg-August-Universität und der königl. Gesellschaft der Wissenschaften (Göttingen).
Handl. Svensk. Vet. Akad.	Handlingar K. Svenska Vetenskaps Akademien (Stockholm).
Jahrb. f. Photog.	Jahrbruch für Photographie (Eder).
J. Chem. Soc.	Journal of the Chemical Society of London.
J. de Phys.	Journal de Physique.
J. Physiol.	Journal of Physiology.
J. prakt Chem.	Journal für praktische Chemie.
J. Russ. Phys.-Chem. Soc.	Journal of the Russian Physico-Chemical Society (in Russian).
J. Soc. franç. de Phys.	Journal de la Société française de Physique.
Math. u. naturwiss. Ber. aus Ungarn.	Mathematische und naturwissenschaftliche Berichte aus Ungarn.
Mem. spettr. ital.	Memorie della Società degli spettroscopisti italiani.
Monatsb. Akad. Berl.	Monatsberichte der Akademie der Wissenschaften zu Berlin.
Monatsh. f. Chem.	Monatshefte für Chemie (Wien).
Month. Not. Roy. Ast. Soc.	Monthly Notices of the Royal Astronomical Society of London.
Oefvers. af K. Vet. Akad. Förh.	Oefversigt af K. Svenska Vetenskaps Akademiens Förhandlingar.
Phil. Mag.	London, Edinburgh, and Dublin Philosophical Magazine.
Phil. Trans.	Philosophical Transactions of the Royal Society of London.
Phot. Mittheil.	Photographische Mittheilungen (Vogel).
Phys. Review	Physical Review.
Phys. Revue	Physikalische Revue.
Proc. Phys. Soc.	Procedings of the Physical Society of London.
Proc. Roy. Inst.	Proceedings of the Royal Institution of Great Britain.
Proc. Roy. Soc.	Proceedings of the Royal Society of London.
Rec. des. trav. chim. des Pays-Bas.	Recueil des travaux chimiques des Pays-Bas.
Rend. R. Accad. d. Lincei	Rendiconti della reale Accademia dei Lincei.
Riv. sci. industr.	Rivista scientifico-industriale.
Sitzungsb. Akad. Berl.	Sitzungsberichte der Akademie der Wissenschaften zu Berlin.
Sitzungsb. Akad. München	Sitzungsberichte der königlich baierischen Akademie zu München.
Sitzungsb. Akad. Wien	Sitzungsberichte der Akademie der Wissenschaften zu Wien.
Sitzungsb. phys.-med. Soc. Erlangen	Sitzungsberichte der phys.-medicinischen Societät zu Erlangen.
Skand. Arch. f. Physiol.	Skandinavisches Archiv für Physiologie (Leipzig).
Verh. phys. Gesellsch. Berlin.	Verhandlungen der physikalischen Gesellschaft zu Berlin.
Wien. Anz.	Anzeiger der k. Akademie der Wissenschaften zu Wien.
Zeitschr. f. anal. Chem.	Zeitschrift für analytische Chemie.
Zeitschr. f. anorg. Chem.	Zeitschrift für anorganische Chemie.
Zeitschr. f. Kryst. u. Min.	Zeitschrift für Krystallographie und Mineralogie.
Zeitschr. f. physikal. Chem.	Zeitschrift für physikalische Chemie.
Zeitschr. f. phys. u. chem. Unterr.	Zeitschrift für physikalischen und chemischen Unterricht.
Zeitschr. f. physiol. Chem.	Zeitschrift für physiologische Chemie.
Zeitschr. f. wiss. Microscopie.	Zeitschrift für wissenschaftliche Microscopie.

An International Standard for the Analysis of Iron and Steel.—Sixth Report of the Committee, consisting of Professor W. C. ROBERTS-AUSTEN (*Chairman*), Sir F. ABEL, Mr. E. RILEY, Mr. J. SPILLER, Professor J. W. LANGLEY, Mr. G. J. SNELUS, Professor TILDEN, *and* Mr. THOMAS TURNER (*Secretary*). (*Drawn up by the Secretary.*)

IN the previous report of this Committee it was stated that the work of the British analysts was completed, so far as the four original standards were concerned, and that the results of the analyses conducted by the other Committees were in good agreement with those published by this Committee.

The remaining standard, No. 5, has now been analysed by Messrs. G. S. Packer, J. Pattinson, E. Riley, and J. E. Stead, and the results of their investigations are as follows :—

—	G. S. Packer	J. Pattinson	E. Riley	J. E. Stead	Mean
Combined Carbon	(0·055)	0·034	0·036	0·035	0·035
Silicon . .	0·006	0·005	trace	0·008	0·006
Sulphur . .	0·030	0·030	0·023	0·036	0·030
Phosphorus . .	0·040	0·041	0·041	0·042	0·041
Manganese . .	0·275	0·310	0·258	0·317	0·290
Copper . .	—	—	0·025	—	—

Generally speaking, the agreement in these results is very good. The carbon determination by Mr. Packer is somewhat high, and this is explained by the fact that Mr. Packer's determinatious were made in the laboratory of Messrs. J. Brown and Co., Sheffield ; and as the operations were conducted in the centre of a large works, with dust inevitably in constant circulation, it was not found possible, even by carefully covering the vessels in which the analyses were performed, to obtain strictly concordant results with the combustion of samples so low in carbon content. For this reason, at Mr. Packer's suggestion, his numbers are not reckoned in calculating the mean carbon percentage. The quantity of material operated upon in estimating such small amounts of carbon is necessarily large, and during filtration and other processes in a dusty atmosphere sufficient carbon is added to seriously affect the results.

The manganese determinations vary from a minimum of 0·258 to a maximum of 0·317, and the figures have been carefully checked by the analysts. This difference raises an important question as to the relative accuracy of the methods employed, though such inquiries are outside the present work of the Committee.

Several applications have been received during the past year for samples of the standards from chemists engaged in investigations as to the relative accuracy of various methods of analysis, and it is hoped, now the standards have been prepared and their composition determined with very considerable accuracy, that they may be frequently employed for such purposes of reference.

As the work of the Committee is now completed it is proposed to shortly deposit the standards with the Board of Trade, as originally suggested, or with some other suitable authority, where they will be at the public service.

The Committee do not ask for reappointment.

The Action of Light upon Dyed Colours.—Report of the Committee, consisting of Professor T. E. THORPE (*Chairman*), Professor J. J. HUMMEL (*Secretary*), Dr. W. H. PERKIN, Professor W. J. RUSSELL, Captain W. DE W. ABNEY, Professor W. STROUD, *and* Professor R. MELDOLA. (*Drawn up by the Secretary.*)

DURING the past year the work of this Committee has been continued, and a large number of wool and silk patterns, dyed with various natural and artificial *orange* and *yellow* colouring matters, have been examined with respect to their power of resisting the fading action of light.

The general method of preparing the dyed patterns, and the manner of exposing them under glass, with free access of air and moisture, were the same as already adopted.

The patterns were exposed at Adel, near Leeds, in the grounds of James A. Hirst, Esq., to whom the best thanks of the Committee are again due for his kind permission to do so.

Each dyed pattern was divided into six pieces, one of which was protected from the action of light, while the others were exposed for different periods of time. These 'periods of exposure' were made equivalent to those adopted last year, by exposing, along with the patterns, special series of 'standards,' dyed with the same colouring matters as were then selected for this purpose. The standards were allowed to fade to the same extent as those which marked off the 'fading period' of last year, before being renewed or removing a set of dyed patterns from the action of light. The patterns exposed during the past year are therefore comparable, in respect of the amount of fading which they have experienced, with the red dyes already reported upon.

The patterns were all put out for exposure on June 8, 1893, certain sets being subsequently removed on the following dates:—July 1, July 31, August 26, 1893; February 19, June 12, 1894. Of the five 'periods of exposure' thus marked off, periods 1, 2, 3 were equivalent to each other in fading power, whereas periods 4 and 5 were each equivalent to *four* of the first period in this respect; hence five patterns of each colour have been submitted respectively to an amount of fading equal to 1, 2, 3, 7, and 11 times that of the first 'fading period' selected—viz. June 8 to July 1, 1893.

The dyed and faded patterns have again been entered in pattern-card books in such a manner that they can be readily compared with each other.

The following tables give the general result of the exposure experiments made during the year 1893–94, the colours being divided, according to their behaviour towards light, into the following five classes: very fugitive, fugitive, moderately fast, fast, very fast.

The initial numbers refer to the order of the patterns in the pattern-books. The S. and J. numbers refer to Schultz and Julius's 'Tabellarische Uebersicht der künstlichen organischen Farbstoffen.'

The colours marked thus (*) appear to be somewhat faster than the rest of the class in which they are placed.

In the case of colouring matters requiring mordants, the particular mordant employed is indicated in brackets after the name of the dyestuff.

CLASS I. VERY FUGITIVE COLOURS. (WOOL.)

The colours of this class have faded so rapidly that at the end of the first 'fading period' (June 8 to July 1, 1893) only a very faint colour remains, or it has become very materially altered in hue. At the end of the fifth period (one year) all traces of the original colour have disappeared, the woollen cloth being either quite white or merely of a yellowish or brownish tint.

Nitro Colours.

Wool Book III.
Acid Yellows. 9. Aurantia. Ammonium salt of hexa-nitro-diphenylamine. S. and J. 14.
" 32. *Brilliant Yellow. Sodium salt of dinitro-α-naphthol-α-sulphonic acid. S. and J. 12.
" 37. *Naphthol Yellow. Sodium salt of dinitro-α-naphthol. S. and J. 9.
" 38. *Naphthol Yellow S. Sodium salt of dinitro-α-naphthol-β-sulphonic acid. S. and J. 11.
" 43. Picric acid. Tri-nitro-phenol. S. and J. 1.

Azo Colours.

Wool Book IV.
Mordant Colours. 14. *Wool Yellow (Cr.). From azo derivative of aniline and maclurin. S. and J. 32.
Wool Book III.
Basic Yellows. 4. Chrysoïdine. From aniline and *m*-phenylene-diamine. S. and J. 31.
Direct Cotton Colours. 1. Terra Cotta F. From primulin and *m*-phenylene-diamine-azo-naphthionic acid.
" 9 Direct Orange RR. Constitution not published.
" 26. Thiazol Yellow. From azo derivative of dehydro-thio-toluidine-sulphonic acid, and dehydro-thio-toluidine-sulphonic acid. S. and J. 98.
" 28. Mimosa Yellow. From azo derivative of primulin, and ammonia.
" 30. Direct Yellow TS. Constitution not published.
" 36. Direct Orange R. Constitution not published.
" 39. Direct Yellow ASC. Constitution not published.

Diphenylmethan Colours.

Basic Colours. 7. Auramine. Imido-tetra-methyl-diamido-diphenyl-methan-hydrochloride. S. and J. 260.

Triphenylmethan Colours.

Acid Colours. 48. Uranin A. Sodium salt of fluoresceïn. S. and J. 315.

Quinoline Colours.

Basic Colours. 42. Quinoline Yellow (sol. in spirit). Quino-phthalone. S. and J. 378.

Acridine Colours.

" 1. Acridine Orange R. extra. Zinc salt of tetra-methyl-diamido-phenyl-acridine.
" 2. Acridine Orange NO. Zinc salt of tetra-methyl-diamido-acridine. S. and J. 381.
" 3. Phosphine. Diamido-phenyl-acridine-nitrate. S. and J. 382.
" 6. Benzoflavine. Diamido-phenyl-di-methyl-acridine hydrochloride. S. and J. 383.

Thiobenzenyl Colours.

Wool Book III.
Basic Colours. 9. Thioflavin T. Dimethyl-dehydro-thio-toluidine-methyl chloride. S. and J. 384.
Acid Colour. 29. Thioflavin S. Sodium salt of dimethyl-dehydro-thio-toluidine-sulphonic acid. S. and J. 385.
Direct Cotton Colour. 31. Primulin. Sulphonated product of the interaction of sulphur and *p*-toluidine. S. and J. 386.

Natural Colouring Matters.

Non-mordant Colours. 1. Annatto. Pulp from fruit of Bixa orellana.
„ 2. Saffron. Stigmata of the flower of Crocus sativus.
„ 3. Turmeric. Rhizome of Curcuma tinctoria.
Mordant Colours. 1. Young Fustic (Al.). Wood of Rhus cotinus.
„ 8. Tesu (Al.). Flowers of Butea frondosa.

NOTES.—Certain of the nitro colours show extreme sensitiveness to light by rapidly altering in hue. During the first 'period of exposure,' the rich red-orange colour of Aurantia, for example, soon changes to brown, and the pure lemon-yellow of Picric Acid changes to orange-yellow; in both cases these altered colours fade slowly without any further change in hue, and might almost be placed among the 'moderately fast colours.' Brilliant Yellow, Martius Yellow, and Naphthol Yellow S behave somewhat like Picric Acid, but the alteration in hue is much less pronounced. Thiazol Yellow, Mimosa Yellow, Thioflavin T and S, and Primulin all fade rapidly during the first 'period of exposure' to a yellow-buff, which then appears to be 'moderately fast.'

CLASS II FUGITIVE COLOURS. (WOOL.)

The colours of this class show very marked fading at the end of the second 'fading period' (July 1 to July 31, 1893), and after a year's exposure they have entirely faded, or only a tint remains.

Azo Colours.

Wool Book III.
Acid Colours. 1. Orange R. From xylidine-sulphonic acid and β-naphthol. S. and J. 81.
„ 6. Orange I. From *p*-sulphanilic acid and α-naphthol. S. and J. 72.
„ 14. Narceïn. Sodium bisulphite compound of Orange II. S. and J. 103.
„ 35. Phenoflavin. From *m*-sulphanilic acid and diamido-phenol-sulphonic acid.
Direct Cotton Colours. 4. Benzo Orange R. From benzidine, salicylic and naphthionic acids. S. and J. 173.
„ 5. Salmon Red. Sodium salt of diamido-diphenyl-urea-disazo-naphthionic acid. S. and J. 143.
„ 6. Toluylene Orange R. From *o*-tolidine and *m*-toluylene-diamine-sulphonic acid. S. and J. 197.
„ 8. Cloth Orange. From benzidine, salicylic acid, and resorcinol. S. and J. 170.

Quinoline Colours.

Acid Colours. 41 Quinoline Yellow S. Sodium salt of quino-thalone-disulphonic acid. S. and J. 379.

Natural Colouring Matters.

Wool Book IV.
Mordant Colours. 1. Tesu (Cr.).
„ 3. Young Fustic (Cr.).
„ 15. Anthracine (Cr.). Composition not published.
„ 2. Quercitron Bark (Al.). Bark of Quercus nigra.
„ 3. Old Fustic (Al.). Wood of Morus tinctoria.
„ 6. Flavin (Al.). Quercetin prepared from Quercitron Bark.
„ 7. Persian Berries (Al.). Fruit of Rhamnus saxatilis.
„ 2. Persian Berries (Sn.).
„ 3. Young Fustic (Sn.).
„ 4. Flavin (Sn.).
„ 5. Quercitron Bark (Sn.).
„ 6. Old Fustic (Sn.).
„ 7. Tesu (Sn.).

NOTES.—The fugitive character of Narceïn as compared with Orange II., of which it is merely the sodium bisulphite compound, is very pronounced. The bright orange of Flavin with tin mordant changes rapidly during the first exposing period to an olive-yellow, which may be regarded as 'moderately fast.' A similar change is noticed in the case of Quercitron Bark and Old Fustic with the same mordant, the faded colour of the latter being, however, very dull.

With aluminium and tin mordants Anthracine gives bright but very fugitive colours.

CLASS III. MODERATELY FAST COLOURS. (WOOL.)

The colours of this class show distinct fading at the end of the second period (July 1 to July 31, 1893), which becomes more pronounced at the end of the third period (July 31 to August 26, 1893). A pale tint remains at the end of the fourth 'period of exposure' (August 26, 1893, to February 19, 1894), and at the end of a year's exposure the colour has entirely faded, or, at most, mere traces of colour remain.

Azo Colours.

Wool Book III.
Acid Colours. 2. Orange GT. From toluidine and β-naphthol-mono-sulphonic acid S. S. and J. 41.
„ 4. *Mandarin GR. extra. From *o*-toluidine-mono-sulphonic acid and β-naphthol. S. and J. 78.
„ 5. *Orange II. From *p*-sulphanilic acid and β-naphthol. S. and J. 73.
„ 7. *Orange III. From *m*-nitraniline and β-naphthol-disulphonic acid R. S. and J. 33.
„ 10. Dimethylaniline Orange. From *p*-sulphanilic acid and dimethylaniline. S. and J. 74.
„ 11. *Diphenylamine Orange. From *p*-sulphanilic acid and diphenylamine. S. and J. 75.
„ 12. Tropæolin Y. From *p*-sulphanilic acid and phenol. S. and J. 70.
„ 15. *Metanil Yellow. From *m*-sulphanilic acid and diphenylamine. S. and J. 77.
„ 16. Resorcinol Yellow. From *p*-sulphanilic acid and resorcinol. S. and J. 71.
„ 18. *Acid Yellow OO. Constitution not published.
„ 19. *Fast Yellow N. From *p*-toluidine-*o*-sulphonic acid and diphenylamine. S. and J. 79.

Wool Book III.
Acid Colours. 28. *Curcumeïn. Nitro derivative of Diphenylamine Orange. S. and J. 101.
„ 29. *Azoflavin S. Same as Curcumeïn, but more highly nitrated. S. and J. 102.
„ 44. *——. Bromine derivative of Metanil Yellow.
„ 45. Persian Yellow (G). Constitution not published.
Direct Cotton Colours. 2. Salmon Red. Constitution not published.
3. Congo Orange R. From tolidine, β-naphthylamine-disulphonic acid R and phenol (ethylated). S. and J. 202.
„ 7. Congo Orange G. From benzidine, β-naphthylamine-disulphonic acid R and phenol (ethylated).
„ 10. Toluylene Orange G. From tolidine, *o*-cresotinic acid, and *m*-toluylene-diamine-sulphonic acid. S. and J. 196.
„ 23. Carbazol Yellow. From diamido-carbazol and salicylic acid. S. and J. 181.
„ 24. *Cotton Yellow G. Sodium salt of diamido-diphenyl-urea-disazo-salicylic acid. S. and J. 144.
Wool Book IV.
Mordant Colour. 24. Mordant Yellow (Cr.). Constitution not published.

Triphenylmethan Colours.

Wool Book III.
Acid Colours. 33. Aurotin. Sodium salt of tetra-nitro-phenol-phthaleïn. S. and J. 314.

Natural Colouring Matters.

Wool Book IV.
Mordant Colours. 5. Weld (Al.). Reseda luteola (whole plant).

NOTES.—The following colours become somewhat duller and apparently darker during the first and second periods of exposure :—Diphenylamine Orange, Metanil Yellow, Fast Yellow N, Azo-flavin S, Acid Yellow OO, and Aurotin. This appearance is only observed when the patterns are examined 'underhand,' *i.e.* by looking down into the fabric; when they are examined 'overhand,' *i.e.* by glancing along the surface, a normal fading of the colours is observed. This darkening is probably due to the presence of the diphenylamine group in the first four colours mentioned, and to the presence of the nitro group in the case of Aurotin, of which the alteration in hue reminds one of the change occurring in Picric Acid Yellow, though it is less pronounced.

Mordant Yellow with aluminium and tin mordants gives colours which may well be classed with the fast colours.

CLASS IV. FAST COLOURS. (WOOL.)

The colours of this class show comparatively little fading during the first, second, and third periods. At the end of the fourth 'period of exposure' a pale shade remains, which at the end of the year's exposure still leaves a pale tint.

Nitro Colours.

Wool Book III.
Acid Colours. 3. *Palatine Orange. Ammonium salt of tetra-nitro-γ-diphenol. S. and J. 8.

Hydrazone Colours.

Acid Colours. 36. Tartrazin. Sodium salt of diphenyl-*p*-sulphonic-acid-osazone-dioxytartaric acid. S. and J. 19.
39. Nitrazin Yellow. Sodium salt of dinitro-dixylyl-*p*-sulphonic acid-osazone-dioxytartaric acid.

Azo Colours.

Wool Book III.
Acid Colours. 23. *Acid Yellow. Sodium salt of amido-azo-benzene-disulphonic acid. S. and J. 21.
" 24. *Fast Yellow. Sodium salt of amido-azo-toluene-disulphonic acid. S. and J. 22.
" 25. Brilliant Yellow S. Sulphonated Diphenylamine Orange. S. and J. 76.
31. *Milling Yellow OO. Constitution not published.
" 34. *Milling Yellow. From β-naphthylamine-α-sulphonic acid and salicylic acid.
Direct Cotton Colours. 11. Titan Yellow R. From thio-*p*-toluidine-sulphonic acid. (Constitution not published.)
" 12. Chrysamin R. From *o*-tolidine and salicylic acid. S. and J. 195.
" 13. Cresotin Yellow R. From *o*-tolidine and *o*-cresol-carboxylic acid.
" 16. Chrysophenin. Ethylated Brilliant Yellow from diamido-stilbene-disulphonic acid. S. and J. 156.
" 17. Cresotin Yellow G. From benzidine and *o*-cresol-carboxylic acid.
" 19. Diamine Yellow N. From ethoxy-benzidine, phenol, and salicylic acid (ethylated). S. and J. 204.
" 21. Chrysamin G. From benzidine and salicylic acid. S. and J. 166.
" 22. *Oriol Yellow. From dehydro-thio-*p*-toluidine-sulphonic acid and salicylic acid. S. and J. 99.
" 38. Titan Yellow Y. From thio-*p*-toluidine-sulphonic acid. (Constitution not published.)
Wool Book IV.
Mordant Colours. 12. Chrome Orange (Cr.). Constitution not published.
" 13. Yellow for wool A F (Cr.). Constitution not published.
" 20. Chrome Yellow (Cr.). Constitution not published.

Oxyketone Colours.

Mordant Colours. 25. Galloflavin (Cr.). Oxidation product of gallic acid. S. and J. 242.
" 26. Alizarin Yellow A (Cr.). Tri-oxy-benzophenone. S. and J. 237.

Natural Colouring Matters.

Mordant Colours. 2. Persian Berries (Cr.).
" 8. Weld (Sn.).

NOTES.—In Palatine Orange we meet with the first example of a colour fast to light, the manufacture of which has already been abandoned; possibly some difficulty or expense connected with its manufacture may account for this circumstance.

Yellow for wool AF, applied with aluminium mordant, is very fugitive, while Chrome Orange seems quite as fast as with chromium. Chrome Yellow with aluminium mordant may be classed as a 'moderately fast' colour.

Galloflavin with aluminium and tin mordants gives fugitive colours, more especially with aluminium.

CLASS V. VERY FAST COLOURS.

The colours of this class show a very gradual fading during the different periods, and even after a year's exposure a moderately good colour remains.

Azoxy Colours.

Wool Book III.

Direct Cotton Colours. 20. Curcumin S. Sodium salt of azoxy-stilbene-disulphonic acid. S. and J. 16.

„ 33. Mikado Orange 3 RO. Constitution not published. S. and J. 18.

„ 35. Mikado Orange GO. Constitution not published. S. and J. 18.

Azo Colours.

Acid Colours. 13. Orange GG. From aniline and β-naphthol-disulphonic acid G. S. and J. 28.

Wool Book IV.

Mordant Colours. 10. *Alizarin Yellow R (Cr.). From *p*-nitraniline and salicylic acid. S. and J. 35.

„ 17. *Anthracene Yellow C (Cr.). Constitution not published.

„ 18. *Diamond Yellow R (Cr.). From *o*-amido-benzoïc acid and salicylic acid. S. and J. 231.

„ 19. *Alizarin Yellow GGW. (Cr.). From *m*-nitraniline and salicylic acid. S. and J. 34.

„ 21. *Gambine Yellow (Cr.). Constitution not published.

„ 22. *Diamond Yellow G (Cr.). From *m*-amido-benzoïc acid and salicylic acid. S. and J. 230.

„ 23. *Flavazol (Cr.). From *p*-toluidine and salicylic acid.

Direct Cotton Colours. 14. Brilliant Yellow. From diamido-stilbene-disulphonic acid and phenol. S. and J. 149.

„ 15. Hessian Yellow. From diamido-stilbene-disulphonic acid and salicylic acid. S. and J. 154.

„ 37. Chloramine Yellow. Oxyphenin.

Oxyketone Colours.

Mordant Colours. 9. *Alizarin Orange W (Cr.) (Al.). β-nitro-alizarin. S. and J. 251.

Natural Colouring Matters.

Mordant Colours. 4. *Flavin (Cr.).

„ 6. *Quercitron Bark (Cr.).

„ 7. *Weld (Cr.).

„ 8. *Old Fustic (Cr.).

„ 16. *Xanthaurin (Cr.). Composition not published.

NOTES.—The brownish-red given by Alizarin Orange W with chromium mordant becomes, during the first 'fading period,' distinctly bluer in shade, and hence apparently darker; the altered colour then fades so slowly that even after a year's exposure the faded colour appears almost as dark as the original.

The azo colours in this class which have been dyed on chromium mordanted wool leave, at the end of a year's exposure, faded colours of greater body and fulness than those applied without mordant; this is no doubt due to the inferior fastness of the latter, the faded colours of which are covered with a thin layer of perfectly bleached fibres.

All the artificial azo-mordant-colours in this class were fixed with aluminium as well as chromium mordant, and found to be equally fast to light. They were also applied with a tin mordant, but only in a few cases were satisfactory level colours thus obtained, and these seemed to be inferior to those applied with an aluminium mordant, in point of brilliancy as well as of fastness to light.

SILK PATTERNS.

Most of the foregoing colours were also dyed on silk, and the patterns were exposed to light along with those on wool. The relative fastness of the various colours was, for the most part, the same as on wool, the differences observed being too unimportant to necessitate a special classification for silk. In Class IV., Yellow for wool A F (Cr.) proved to be much more fugitive on silk, whereas Chrysamin R and G, Titan Yellow R and Y, Oriol, Cresotin Yellow R and G, and Chrysophenin appeared to be somewhat faster. In Class III. the same remark applies to Cotton Yellow G.

The Indian dye-stuff Kamála was an additional one applied to silk, and found to belong to the fugitive class, being very little faster than Annatto.

GENERAL OBSERVATIONS.

The first thing which strikes one when examining these orange and yellow patterns is the comparatively large number of satisfactorily permanent colours.

In the more or less fugitive class are to be found all the basic colours, all the nitro-phenols, with the exception of Palatine Orange, and all the bright yellows derived from the natural colouring matters by means of aluminium and tin mordants, with the exception of those obtained from Weld. Comparatively few azo colours are met with in this group.

The marked alteration in colour from yellow to orange shown in the case of Picric Acid has long been known, and is ascribed to a reducing action of the light. The equally striking change from orange to brown, shown by Aurantia, does not, however, seem to have been previously recorded.

By far the largest number of yellows, ranging from 'moderately fast' to 'very fast,' are to be found among the azo colours. Specially important are those in which salicylic acid is a constituent element, since not only does this impart to the colour the power of forming more or less stable lakes with chromium and aluminium mordants, but it appears frequently to give the colours the quality of fastness to light, even when no mordant is applied. It is a fact of some importance that the colours obtained with aluminium are practically as fast as those fixed with chromium, since the first-named mordant gives much brighter and purer yellows. The tin mordant, so useful in the production of the most brilliant orange and yellow colours obtainable from the natural colouring matters, seems, however, to be of little or no advantage in connection with most of these azo-mordant-colours, no doubt because they are susceptible to the reducing action of the mordant usually employed for wool—viz. stannous chloride.

Very interesting in point of fastness to light are the azoxy colours, and although unfortunately apt to dye wool somewhat irregularly, giving speckled-looking colours, they are admirably adapted for silk and cotton.

Another interesting little group is that which includes Tartrazin, a colour not only noteworthy for its fastness to light, but also because of its brilliancy and purity.

The fastness of Alizarin Orange is worthy of special mention, for it is probably greater even than that exhibited by most other colours of the

Alizarin group, and it shows the peculiar darkening action exerted by the light, probably in consequence of the presence of the nitro group.

It is remarkable how few really fast yellows are derived from the natural colouring matters, and these are chiefly the olive-yellows obtained with chromium mordant. The only fast, and at the same time bright, natural yellows are those derived from Weld, and since this dye-stuff is now of little general importance to the dyer its cultivation has become extremely limited, and is gradually being given up; it is fortunate, therefore, that science has been able to replace it by efficient substitutes, so far, at least, as permanency towards light is concerned.

Our experiments have already abundantly proved that the popular opinion that the coal tar dye-stuffs include only such as yield more or less fugitive colours is entirely false; indeed, it is perfectly safe to assert that coal-tar is the source from which the greatest number of colours fast to light are derived at the present time, and this seems to be specially true of the red and yellow colours.

Bibliography of Solution.—Interim Report of the Committee, consisting of Professor W. A. TILDEN (*Chairman*), Dr. W. W. J. NICOL (*Secretary*), Professor H. MCLEOD, Mr. S. U. PICKERING, Professor W. RAMSAY, *and* Professor SYDNEY YOUNG.

THE Committee have collected the titles of all papers on solution published before 1874 in the journals catalogued by the Royal Society, the arrangement and classification of these are well advanced, and the Committee hope that this portion of the work will be completed and ready for publication at the next meeting of the Association.

Proximate Chemical Constituents of Coal.—Interim Report of the Committee, consisting of Sir I. LOWTHIAN BELL (*Chairman*), Professor P. PHILLIPS BEDSON (*Secretary*), Mr. LUDWIG MOND, Professor VIVIAN B. LEWES, Professor E. HULL, Mr. J. W. THOMAS, *and* Mr. H. BAUERMAN.

OF the proximate constituents of the organic material forming coal our knowledge is limited to the demonstrated existence in it of certain gaseous hydrocarbons which have been extracted under conditions such as to lead to the belief that these gases exist occluded or enclosed in the coal itself. Further, certain mineral substances (containing carbon, hydrogen, and oxygen) of a more or less defined character have been met with from time to time in association with coal, and also some few solid hydrocarbons.

The literature bearing upon this subject is extremely meagre, but it appears that the action of some solvents on coal has formed the subject of investigation by several chemists. Ether, alcohol, petroleum ether, benzene, and phenol have been used as solvents by different observers. The last named was found by Guignet to dissolve from 2 to 4 per cent. of a brown amorphous solid from a fat coal. Guignet has also observed that, by the action of nitric acid on coal, oxalic acid and trinitro-resorcinol are produced; further, there are formed insoluble substances, apparently similar to 'nitro-cellulose,' which explode on heating.

For the purposes of a preliminary study a coal representing the Hutton seam in the county of Durham was selected. This coal is a bituminous coal, and is used as a gas coal. When heated with ether it yields up to the solvent a small amount of a substance which imparts a light yellow colour to the ether, and a blue fluorescence is observed, similar to that noted by Dondorff in his experiments with a gas coal of the Westphalia Coalfield. Alcohol, benzene, and petroleum ether dissolve but little from the coal, the solutions being in each case similar to that obtained with ether.

Acetic anhydride and glacial acetic acid were employed as solvents with but little effect. Somewhat more promising at first were the results obtained by using a solution of sulphur dioxide in glacial acetic acid. The coal was heated at 100° C. with this solution in tightly closed flasks. The liquid becomes dark in colour, and on adding water to the solution a light yellow precipitate is formed. The precipitate is dissolved by ether, and the ethereal solution on evaporation leaves an oily residue, which was found to be partially volatile in steam.

Turpentine heated at 150° C. in a tightly closed flask with the powdered coal dissolves some constituent, becoming darker in colour and acquiring a greenish-blue fluorescence.

When the coal is heated with aniline a brown amorphous solid is dissolved out, which is precipitated from the aniline on acidifying with hydrochloric acid. This substance is not unlike that obtained by Guignet by treatment of coal with phenol. It was attempted to separate this solid into several fractions by treatment with alcohol and benzene. The alcoholic and benzene solutions, however, left merely resinous substances on evaporation. Dilute solutions of potassium permanganate oxidise this solid, forming dark brown solutions containing potassium carbonate and the potassium salts of organic acids. The quantity of material being small, it was next decided to treat the coal itself with potassium permanganate. For this purpose finely powdered coal is suspended in water, to which, when boiling, potassium permanganate is added in small quantities at a time. The colour of the permanganate gradually disappears, and an odour resembling that of turpentine is observed; at the same time a dark brown alkaline liquid is formed.

The amount of permanganate which is thus reduced by the coal is considerable: in one case where 500 grams of coal were taken, some 1,600 grams of permanganate were employed without exhausting the reducing power of the coal, of which some 25 to 30 per cent. had been oxidised in this manner.

The aqueous solution decanted off from the manganese dioxide and coal is very dark in colour, becoming almost black when concentrated.

Amongst the acids formed in this way, oxalic acid has been found, together with some deliquescent acids, which on the evaporation of their aqueous solutions are left as brown resinous masses. The separation of these products is still incomplete, and it would be futile to give the results of the analyses of the salts which have been prepared. The barium salts appear to afford a means of separating the acids, some of which salts have been already obtained in a fairly pure condition. The account of these acids and the study of the action of potassium permanganate on other coals it is proposed to deal with in a subsequent report.

Wave-length Tables of the Spectra of the Elements and Compounds.—Report of the Committee, consisting of Sir H. E. ROSCOE, Dr. MARSHALL WATTS, Mr. J. N. LOCKYER, Professors J. DEWAR, G. D. LIVEING, A. SCHUSTER, W. N. HARTLEY, *and* WOLCOTT GIBBS, *and* Captain ABNEY. (*Drawn up by* Dr. WATTS.)

CHROMIUM (ARC SPECTRUM).

Hasselberg: 'Kongl. Svenska Vetenskaps-Akadem. Handl.,' Bd. 26, No. 5, 1894.

* Coincident with a solar line.
† See Iron.
‡ See Calcium.
§ See Nickel.

Rowland's Normal solar lines (on which these measurements of the Chromium lines rest) are given at the foot of page 255.

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$	
*5797·02	1	1·58	4·7	17245·5
5792·00	1	"	"	17260·5
*5791·20	6	"	"	17262·9
5788·63	1·5	"	"	17270·5
*5788·15	5	"	"	17272·0
5787·26	1·5	"	"	17274·6
5786·00	3	"	"	17278·4
*5785·21	4	"	"	17280·7
*5784·09	4	"	"	17284·1
*5783·32	3	"	"	17286·4
*5782·01	2	"	"	17290·3
*5781·43	2	"	"	17292·1
5781·20	1·5	"	"	17292·7
*5753·88	1·5	1·57	"	17374·9
5746·65	1·5	"	"	17396·7
5738·77	1·5	1·56	"	17420·7
5736·88	1	"	"	17426·4
5729·42	1·5	"	"	17449·1
5720·06	1·5	"	4·8	17477·5
*5713·03	3	"	"	17499·0
*5712·87	1·5	"	"	17499·5
*5702·56	3	1·55	"	17531·2
5700·75	1·5	"	"	17536·7
*5698·55	4	"	"	17543·5
*5694·93	3	"	"	17554·7
5683·76	1n	"	"	17589·2
5682·67	2n	"	"	17592·6
5681·39	1·5n	"	"	17596·5
5674·42	1	"	"	17618·1
*5664·26	3	1·54	"	17649·8
*5658·85	1·5	"	"	17666·5
5649·60	2	"	"	17695·5
5642·60	1·5	"	"	17717·5
*5638·35	1	"	"	17730·9
*5628·87	3	"	"	17760·7
*5480·71	3	1·50	5·0	18240·8
*5464·16	3	1·49	"	18296·1
5442·61	2	"	"	18368·5
5432·56	1	1·48	5·0	18402·5
*5409·99	10	"	"	18479·3
*5405·22	2	"	"	18495·6
5400·82	4	1·47	5·1	18510·6
5391·57	2	"	"	18542·4
*5390·60	2	"	"	18545·7
*5387·76	3	"	"	18555·5
*5387·17	3	"	"	18557·5
5377·82	1	"	"	18589·8
*5373·92	1·5	"	"	18603·3
*5370·57	1·5	"	"	18614·9
*5368·73	1·5	"	"	18621·3
*5348·50	8	1·46	"	18691·7
*5345·98	8	"	"	18700·5
5344·98	1·5	"	"	18704·0
*5340·66	2	"	"	18719·2
*5329·91	3n	"	"	18757·0
*5329·30	4n	"	"	18759·1
†*5328·50	8n	"	"	18761·9
*5318·97	2	1·45	"	18795·5
*5313·05	2	"	"	18816·5
*5304·37	2	"	"	18847·3
*5300·90	5	"	5·2	18859·6
*5298·43	8	"	"	18868·3
*5298·14	4n	"	"	18869·4
*5297·52	5n	"	"	18871·6
*5296·86	8	"	"	18873·9
5293·57	1	"	"	18885·6
*5287·36	1·5	1·44	"	18907·8
*5280·48	1·5	"	"	18932·5
*5276·20	6	"	"	18947·8
*5275·85	4	"	"	18949·1
*5275·31	6	"	"	18951·0
†*5273·57	2	"	"	18957·3
*5272·17	2	"	"	18962·3
*5265·88	6	"	"	18985·0
*5265·31	3	"	"	18987·0
*5264·32	8	"	"	18990·6

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$				λ+	$\frac{1}{\lambda}-$	
‡*5261·91	2	1·44	5·2	18999·3	*4936·51	4	1·35	5·6	20251·6
*5255·27	4	"	"	19023·3	4930·36	1·5	"	"	20276·9
*5255·08	3	"	"	19024·0	*4922·40	5	"	"	20309·7
*5247·68	6	1·43	"	19050·8	*4921·11	2	"	"	20315·0
*5243·53	2	"	"	19065·9	4903·40	3	1·34	"	20388·4
5241·62	1	"	"	19072·9	4888·69	2	"	"	20449·8
*5240·62	1	"	"	19076·5	4887·15	4	"	"	20456·2
*5239·13	2	"	"	19081·9	*4886·11	1·5	"	"	20460·6
*5228·25	1·5	"	"	19121·7	*4885·92	3	"	"	20461·4
†*5227·04	1·5	"	"	19126·1	4885·12	1·5	"	"	20464·7
*5225·98	1·5	"	"	19130·0	4874·81	1	1·33	"	20508·0
*5225·17	1·5	"	"	19132·9	*4870·96	5	"	"	20524·2
*5225·08	4	"	"	19133·3	*4862·00	4	"	5·7	20561·9
*5224·70	1·5	"	"	19134·7	4861·38	2	"	"	20564·6
*5224·22	1	"	"	19136·4	4857·50	1	"	"	20581·0
*5222·83	1	"	"	19141·5	4855·32	1	"	"	20590·3
*5221·90	2	"	"	19144·9	*4851·65	1·5	"	"	20605·8
*5221·06	1·5	"	"	19148·0	*4848·39	1	"	"	20619·7
*5214·30	1·5	"	"	19172·8	*4837·00	1·5	1·32	"	20668·2
†*5208·58	10nr	1·42	5·3	19193·8	*4831·79	1·5	"	"	20690·6
5206·20	10nr	"	"	19202·6	*4829·50	4	"	"	20700·4
†5204·67	10nr	"	"	19208·2	*4824·31	1	"	"	20722·7
*5200·33	1·5	"	"	19224·2	4824·10	1	"	"	20723·6
*5196·60	4	"	"	19238·1	4816·31	1·5	"	"	20757·1
*5193·66	1·5	"	"	19248·9	*4814·44	1·5	"	"	20765·1
*5192·17	3	"	"	19254·5	*4810·91	1·5	"	"	20780·4
§*5184·73	2	"	"	19282·1	*4806·44	1·5	"	"	20799·7
*5177·58	2	"	"	19308·7	*4801·17	4	1·31	"	20822·6
*5166·41	3	1·41	"	19350·5	*4796·29	2	"	"	20843·7
*5161·98	1·5	"	"	19367·1	*4792·61	4	"	"	20859·8
*5144·87	1·5	"	"	19431·5	*4790·44	2	"	"	20869·2
*5142·46	1	"	"	19440·6	*4789·45	5	"	"	20873·5
*5139·82	3	"	"	19450·6	*4783·16	1·5n	"	5·8	20900·9
*5123·64	2	1·40	"	19512·1	*4775·25	1·5	"	"	20935·5
5122·98	1	"	"	19514·6	4774·63	1	"	"	20938·2
*5122·30	1·5	"	"	19517·2	*4770·80	1	"	"	20955·0
*5113·31	1·5	"	5·4	19551·4	*4767·98	2	"	"	20967·4
5112·70	1	"	"	19553·7	*4767·40	1·5	"	"	20970·0
*5110·93	2	"	"	19560·5	*4766·77	2	1·30	"	20972·8
*5092·08	1	1·39	"	19632·9	4764·81	1·5	"	"	20981·4
5078·92	1	"	"	19683·8	*4764·45	3	"	"	20983·0
*5073·10	2	"	"	19706·4	*4761·43	1	"	"	20996·3
*5068·50	1	"	"	19724·3	†*4757·76	1·5	"	"	21012·5
*5067·90	2	"	"	19726·6	4757·49	1·5	"	"	21013·7
*5066·10	1·5	"	"	19733·6	*4756·30	4	"	"	21018·9
*5052·10	2	1·38	"	19788·3	*4755·36	1·5	"	"	21023·2
5048·96	1	"	"	19800·7	§*4754·95	1·5	"	"	21024·9
*5022·12	1	1·37	5·5	19906·4	4754·10	1	"	"	21028·7
*5013·48	3	"	"	19940·7	§*4752·27	3	"	"	21036·8
*5004·60	1	"	"	19976·1	*4745·48	2	"	"	21066·9
*4986·16	1	1·36	"	20050·0	4743·30	1	"	"	21076·6
*4965·02	3	"	"	20135·4	4741·27	1	"	"	21085·6
*4954·92	4	"	"	20176·5	*4737·50	4	"	"	21102·4
4953·87	1	1·35	"	20180·7	*4730·88	4	"	"	21131·9
*4942·63	4	"	5·6	20226·5	*4729·89	2	1·29	"	21136·3

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	1/λ −	
*4727·33	3	1·29	5·8	21148·1
*4724·60	3	,,	,,	21160·0
*4723·28	3	,,	,,	21165·9
*4722·90	1·5	,,	,,	21167·6
*4718·57	6	,,	,,	21187·1
4717·87	1·5	,,	,,	21190·2
*4708·16	6	,,	,,	21233·9
4706·25	1·5	,,	5·9	21242·4
*4700·77	2	,,	,,	21267·2
4699·76	1·5	,,	,,	21271·8
4699·12	1·5	,,	,,	21274·7
4698·77	4	,,	,,	21276·3
†4698·60	4	,,	,,	21277·0
4697·57	1·5	,,	,,	21281·7
*4697·20	3	,,	,,	21283·4
*4695·32	2	,,	,,	21291·9
*4694·12	3	,,	,,	21297·4
*4689·54	4	1·28	,,	21318·2
§*4686·38	1·5	,,	,,	21332·5
*4684·77	1·5	,,	,,	21339·9
*4681·01	2	,,	,,	21357·0
*4680·65	2	,,	,,	21358·7
*4673·30	1·5	,,	,,	21392·3
*4669·86	1·5s	,,	,,	21408·0
*4669·50	3	,,	,,	21409·7
4667·36	2	,,	,,	21419·5
*4666·67	4	,,	,,	21422·7
*4666·35	3	,,	,,	21424·1
*4666·07	3	,,	,,	21425·4
*4664·94	4	,,	,,	21430·6
*4663·98	4	,,	,,	21435·0
*4663·47	4	,,	,,	21437·4
4657·00	1·5	,,	,,	21467·1
*4656·61	1·5	,,	,,	21468·9
*4656·34	2	,,	,,	21470·2
4654·90	3	,,	,,	21476·8
*4654·24	2n	1·27	,,	21479·9
*4652·31	7	,,	,,	21488·8
*4651·44	7	,,	,,	21492·8
*4649·58	3	,,	,,	21501·4
*4649·04	3	,,	,,	21503·9
4648·27	2	,,	,,	21507·5
*4648·00	1·5	,,	,,	21508·7
*4646·96	1·5	,,	,,	21513·5
*4646·33	7	,,	,,	21516·5
4642·21	1·5	,,	,,	21535·6
*4639·85	1·5	,,	,,	21546·5
*4639·69	2	,,	,,	21547·3
*4637·92	3	,,	,,	21555·5
*4637·35	3	,,	,,	21558·1
*4634·23	1·5	,,	6·0	21572·6
*4633·45	2	,,	,,	21576·2
*4632·32	2	,,	,,	21581·5
*4627·83	1	,,	,,	21602·4
*4626·31	6	,,	,,	21609·5
*4626·07	1·5	1·27	6·0	21610·6
4625·46	1	,,	,,	21613·5
*4622·89	2	,,	,,	21625·5
*4622·60	4	,,	,,	21626·9
*4622·07	4	,,	,,	21629·3
*4619·70	3	,,	,,	21640·4
*4616·28	6	1·26	,,	21656·5
4614·92	1·5	,,	,,	21662·8
§4614·70	1·5	,,	,,	21663·9
*4614·34	1·5	,,	,,	21665·6
*4613·54	5	,,	,,	21669·3
4612·15	1·5	,,	,,	21675·9
*4610·07	1·5	,,	,,	21685·6
4606·55	1·5	,,	,,	21712·2
*4601·18	2	,,	,,	21727·6
*4600·92	6	,,	,,	21728·8
*4600·25	3	,,	,,	21731·9
*4598·60	1·5	,,	,,	21739·7
*4595·78	4	,,	,,	21753·1
4594·57	1.5	,,	,,	21758·7
*4591·56	6	,,	,,	21773·1
4590·88	1·5	,,	,,	21776·3
*4588 38	1·5	,,	,,	21788·2
4586·31	2	,,	,,	21798·0
4585·23	1·5	,,	,,	21803·2
4585·08	1·5	,,	,,	21803·9
4584·25	1·5	,,	,,	21807·8
4584·02	1·5	,,	,,	21808·9
4581·22	1·5	,,	,,	21822·2
*4580·22	5	1·25	,,	21827·0
4578·55	1·5	,,	,,	21835·0
4575·26	2	,,	,,	21850·7
*4574·63	1	,,	,,	21853·7
*4571·85	4	,,	,,	21867·0
*4571·27	1·5	,,	,,	21869·8
*4569·76	5	,,	,,	21877·0
*4565·71	4	,,	,,	21896·4
*4564·36	2	,,	6·1	21902·8
4563·82	3	,,	,,	21905·4
*4563·43	1·5	,,	,,	21907·2
*4558·81	2	,,	,,	21929·4
*4556·32	3	,,	,,	21941·4
4555·45	1·5	,,	,,	21945·6
4554·98	2	,,	,,	21947·9
4554·10	1·5	,,	,,	21952·1
*4546·15	6	,,	,,	21990·5
*4545·51	3	,,	,,	21993·6
*4544·77	5	,,	,,	21997·2
*4543·99	1·5	,,	,,	22001·0
*4542·83	2	1·24	,,	22006·6
*4541·70	2	,,	,,	22012·1
*4541·25	3	,,	,,	22014·3
*4540·90	6	,,	,,	22016·0
*4540·70	6	,,	,,	22016·9
*4539·96	4	,,	,,	22020·5

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	1/λ −				λ+	1/λ −	
*4535·95	6	1·21	6·1	22050·0	†4422·84	1·5	1·21	6·3	22603·6
*4535·36	3	"	"	22052·9	4421·12	1	"	"	22612·4
*4530·92	6	"	"	22064·5	*4419·26	1	"	"	22621·9
4530·04	3	"	"	22068·8	*4414·00	2	"	"	22648·9
*4527·65	3	"	"	22080·4	*4412·42	2	"	"	22657·0
*4527·53	4	"	"	22081·0	*4411·26	2	"	"	22663·0
*4526·65	6	"	"	22085·3	4411·15	1·5	"	"	22663·5
*4526·26	3	"	"	22087·2	*4410·47	2	"	"	22667·0
4525·01	2	"	"	22093·3	4406·45	1	"	"	22687·7
4522·18	1·5	"	"	22107·1	*4403·68	2	"	"	22702·0
4521·30	3	"	"	22111·4	*4403·55	2	"	"	22702·6
4515·60	3	"	"	22139·4	*4399·97	1·5	"	"	22721·1
*4514·64	3	"	"	22144·1	*4397·40	2	"	"	22734·4
*4512·05	4	"	"	22156·8	4395·58	1·5	"	"	22743·8
*4507·00	3	"	"	22181·6	*4395·00	1n	"	"	22746·8
*4501·92	2	1·23	"	22206·6	*4393·66	1·5	1·20	"	22753·8
*4501·24	3	"	"	22210·0	*4392·41	1	"	"	22760·2
*4500·42	3	"	"	22214·0	*4391·90	3	"	"	22762·9
*4498·87	3	"	"	22221·7	4387·64	3	"	"	22785·0
*4497·02	5	"	6·2	22230·8	4387·54	1·5	"	"	22785·5
4495·42	1·5	"	"	22238·7	*4385·11	6	"	"	22798·2
*4492·45	3	"	"	22253·4	4383·04	1·5	"	"	22808·9
*4491·99	1·5	"	"	22255·6	*4381·25	2	"	"	22818·2
*4491·81	2n	"	"	22256·5	*4380·73	1	"	"	22820·9
*4490·70	1·5n	"	"	22262·0	*4379·93	1·5	"	"	22825·1
*4489·60	2	"	"	22267·5	*4377·73	1·5	"	"	22836·6
4488·18	2	"	"	22274·5	†*4376·95	2	"	"	22840·7
*4483·01	2	"	"	22300·2	*4375·52	3	"	"	22848·1
4481·57	1·5	"	"	22307·4	*4374·34	4	"	"	22854·3
*4480·40	1·5	"	"	22313·2	4373·83	1·5	"	"	22857·0
†*4475·47	2n	"	"	22337·8	*4373·41	4	"	"	22859·2
4473·91	1·5	"	"	22345·6	*4371·44	6	"	"	22869·5
*4467·72	1·5	1·22	"	22376·6	§*4368·42	1·5	"	6·4	22885·2
4466·33	1·5	"	"	22383·5	*4363·25	3	"	"	22912·3
*4465·54	2	"	"	22387·5	4360·17	1·5	"	"	22928·5
*4465·31	1	"	"	22388·7	*4359·78	6	"	"	22930·5
4465·08	2	"	"	22389·8	*4358·86	1	"	"	22935·4
†*4464·84	1·5	"	"	22391·0	*4357·70	1·5	"	"	22941·5
4462·98	1·5	"	"	22400·3	*4356·91	1·5	1·19	"	22945·6
*4460·95	1·5	"	"	22410·6	*4351·91	8	"	"	22972·0
*4459·95	3	"	"	22415·6	*4351·20	6	"	"	22975·8
*4459·56	1·5	"	"	22417·5	*4347·00	3	"	"	22998·0
*4458·75	3	"	"	22421·6	*4344·66	7	"	"	23010·4
*4443·90	1·5	"	"	22496·6	4343·33	1·5	"	"	23017·5
4442·43	1·5	"	"	22504·0	*4340·26	3	"	"	23033·7
4432·93	1	"	"	22552·2	*4339·85	6	"	"	23035·9
*4432·30	3n	"	"	22555·4	*4339·60	6	"	"	23037·2
4430·59	2	1·21	6·3	22564·1	*4338·95	1·5	"	"	23040·7
4430·07	1·5	"	"	22566·7	*4338·56	1·5	"	"	23042·7
*4428·71	2	"	"	22573·6	*4337·70	3	"	"	23047·3
4427·85	1	"	"	22578·0	*4337·38	2	"	"	23049·0
*4425·27	1	"	"	22591·2	*4332·75	1·5	"	"	23073·6
*4424·40	3	"	"	22595·6	4325·24	1·5	"	"	23113·7
*4424·20	1·5	"	"	22596·7	*4323·70	2	"	"	23121·9
4423·46	1·5	"	"	22600·4	*4321·80	2	"	"	23132·1

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$				λ+	$\frac{1}{\lambda}-$	
4321·44	1·5	1·19	6·4	23134·0	*4207·05	1·5	1·16	6·6	23763·0
*4320·75	1·5	"	"	23137·7	*4204·61	2	1·15	"	23776·8
*4319·82	2	"	"	23142·7	*4204·37	1·5	"	"	23778·2
*4312·65	1·5	1·18	"	23181·2	*4203·71	3	"	"	23781·9
*4307·65	1·5	"	6·5	23208·0	*4200·27	2	"	6·7	23801·3
†*4305·61	2	"	"	23219·0	4198·65	3	"	"	23810·5
*4302·95	1·5	"	"	23233·4	*4197·38	2	"	"	23817·7
*4301·33	2	"	"	23242·1	4195·09	2	"	"	23830·7
*4300·68	2	"	"	23245·6	4193·80	2	"	"	23838·0
4299·87	2	"	"	23250·0	4192·25	2s	"	"	23846·8
*4297·91	3	"	"	23260·6	4191·90	1·5	"	"	23848·8
4297·21	2	"	"	23264·4	*4191·41	2	"	"	23851·6
*4296·81	1	"	"	23266·6	*4190·32	2	"	"	23857·8
*4296·47	1	"	"	23268·4	*4186·50	1.5	"	"	23879·6
*4295·92	3	"	"	23271·4	*4185·50	1·5	"	"	23885·3
*4293·73	2	"	"	23283·3	*4179·37	3	"	"	23920·4
*4292·14	2	"	"	23291·9	*4176·09	2	"	"	23939·1
*4289·87	10nr	"	"	23304·2	4175·34	1·5	"	"	23943·4
*4284·99	1·5	"	"	23330·8	*4174·98	3	"	"	23945·5
§*4284·84	1·5	"	"	23331·6	†*4172·88	2	"	"	23957·6
*4280·53	3	1·17	"	23355·1	*4171·81	2	"	"	23963·7
*4274·91	10nr	"	"	23385·8	4170·31	2	"	"	23972·3
*4273·04	2	"	"	23396·0	4169·94	2	"	"	23974·5
4271·18	2	"	"	23406·2	4165·67	3	1·14	"	23999·0
*4270·08	1·5	"	"	23412·3	*4163·76	4	"	"	24010·1
*4268·90	1·5	"	"	23418·7	*4161·55	3	"	"	24022·8
*4266·96	1	"	"	23429·4	4153·96	4	"	"	24066·7
*4263·28	4	"	"	23449·6	*4153·20	1·5	"	"	24071·1
*4262·53	1·5	"	"	23453·7	*4152·89	1·5	"	"	24072·9
4262·27	1·5	"	"	23455·2	*4146·81	1·5	"	6·8	24108·1
4261·77	1·5	"	"	23457·9	§*4142·31	1·5	"	"	24134·3
*4261·49	3	"	"	23459·5	*4131·50	2	"	"	24197·5
*4255·65	2	"	"	23491·7	4128·53	1·5	1·13	"	24214·9
*4254·49	10nr	"	"	23498·1	*4127·77	2	"	"	24219·4
4252·37	2	"	6·6	23509·7	*4127·44	2	"	"	24221·3
*4248·84	1·5	"	"	23529·2	4127·05	1·5	"	"	24223·6
*4248·47	1·5	"	"	23531·3	*4126·67	4	"	"	24225·8
*4240·82	3	1·16	"	23573·7	4126·25	1·5	"	"	24228·3
*4239·08	3	"	"	23583·4	*4123·55	2	"	"	24244·1
*4237·83	1·5	"	"	23590·4	*4122·34	1·5	"	"	24251·3
*4234·64	1·5	"	"	23608·2	*†4121·96	2	"	"	24253·5
*4233·00	1·5	"	"	23617·3	§4121·41	1·5	"	"	24256·7
*4232·35	1·5	"	"	23620·9	*4120·78	2	"	"	24260·4
*4230·61	2	"	"	23630·7	*4109·74	1·5	"	"	24325·6
†*4224·64	2s	"	"	23664·1	4108·54	1·5	"	"	24332·7
*4222·89	2	"	"	23673·9	4104·90	2	"	"	24354·3
4221·71	2	"	"	23680·5	*4101·31	1·5	"	"	24375·7
4217·75	3	"	"	23702·7	*4099·16	1·5	"	6·9	24388·3
*4216·50	2	"	"	23709·8	*4090·43	1·5	1·12	"	24440·4
*4213·31	1·5	"	"	23727·7	†*4085·15	1	"	"	24472·0
*4212·77	2	"	"	23730·8	4081·88	1	"	"	24491·6
*4211·47	2	"	"	23738·1	†*4080·35	1·5	"	"	24490·8
*4209·90	2	"	"	23746·9	4077·81	2	"	"	24515·7
*4209·50	3	"	"	23749·2	*4077·21	2	"	"	24519·7
*4208·50	2	"	"	23754·8	4076·20	2	"	"	24525·8

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
*4075·01	1·5	1·12	6·9	24532·9	*3951·93	1	1·09	7·2	25296·9
4071·13	1	,,	,,	24556·3	3951·26	1·5	,,	,,	25301·2
*4067·94	1	,,	,,	24575·6	*3946·15	1·5	,,	,,	25334·0
4067·05	4	,,	,,	24581·0	3945·68	1	,,	,,	25337·0
*4065·84	3	,,	,,	24588·3	*3941·66	3	,,	,,	25362·8
*4060·77	1·5	,,	,,	24619·0	*3928·79	6	1·08	,,	25445·9
*4058·89	3	,,	,,	24630·4	3926·80	2	,,	,,	25458·8
4056·93	1	,,	,,	24642·3	3923·51	1	,,	,,	25480·2
*4056·17	1·5	,,	,,	24646·9	*3921·20	5	,,	,,	25495·2
*4051·47	1·5	1·11	7·0	24675·4	3920·25	1·5	,,	,,	25501·4
*4050·18	1	,,	,,	24683·3	*3919·31	7	,,	,,	25506·5
*4049·90	1·5	,,	,,	24685·0	*3917·75	1·5	,,	,,	25517·7
4048·94	3	,,	,,	24690·8	*3917·15	1	,,	,,	25521·6
§*4046·89	1	,,	,,	24703·3	*3916·38	4	,,	,,	25526·6
*4044·24	1·5	,,	,,	24719·5	*3915·96	4n	,,	,,	25529·3
*4043·85	1·5	,,	,,	24721·9	*3915·65	1·5	,,	,,	25531·3
*4042·40	1·5	,,	,,	24730·8	*3914·45	1·5	,,	,,	25539·2
*4039·21	3	,,	,,	24750·3	*3908·87	5	,,	7·3	25575·5
*4037·43	1·5	,,	,,	24761·2	*3907·91	2	,,	,,	25581·8
4033·44	1·5	,,	,,	24785·7	3907·40	1	,,	,,	25585·2
*4031·26	1·5	,,	,,	24799·1	3903·30	3	,,	,,	25612·0
4030·82	2	,,	,,	24801·8	3903·02	4	,,	,,	25613·9
*4028·22	1	,,	,,	24817·9	3902·22	2n	,,	,,	25619·1
*4027·24	2	,,	,,	24823·9	3897·83	3n	,,	,,	25648·0
*4026·30	2	,,	,,	24829·7	*3894·20	4	1·07	,,	25671·9
*4025·60	1	,,	,,	24834·0	*3892·07	2n	,,	,,	25686·0
*4025·14	2	,,	,,	24836·9	*3886·94	4	,,	,,	25719·9
*4023·90	1·5	,,	,,	24844·5	*3885·35	4	,,	,,	25730·4
*4022·38	2	,,	,,	24853·9	*3883·78	2	,,	,,	25740·8
4018·36	1	,,	,,	24878·8	†3883·41	4	,,	,,	25743·3
*4016·95	1	,,	,,	24887·5	3881·37	2n	,,	,,	25756·8
4014·85	1	1·10	,,	24900·5	*3879·39	3n	,,	,,	25770·1
4012·63	2	,,	,,	24914·3	*3868·41	1·5	,,	,,	25843·1
4004·11	1	,,	,,	24967·3	3865·73	1·5	,,	,,	25861·0
*4001·58	2	,,	7·1	24983·0	*3862·68	1·5	,,	,,	25881·5
3999·85	1	,,	,,	24993·8	3860·28	1·5	,,	,,	25897·9
*3994·10	1·5	,,	,,	25029·8	3857·74	4	,,	,,	25914·6
*3992·95	3	,,	,,	25037·0	3856·40	2	1·06	,,	25923·6
*3991·81	3	,,	,,	25044·2	*3855·75	3	,,	,,	25928·0
*3991·26	4	,,	,,	25047·6	*3855·41	2	,,	,,	25930·3
*3990·14	2	,,	,,	25054·7	*3854·36	4	,,	,,	25937·3
*3984·48	3	,,	,,	25090·3	*3853·33	1·5	,,	,,	25944·3
*3984·02	5	,,	,,	25093·2	*3852·33	2	,,	,,	25951·0
*3981·37	2	,,	,,	25109·9	3850·13	5n	,,	,,	25965·9
*3979·99	1·5	,,	,,	25118·6	*3849·66	2n	,,	,,	25969·0
*3978·81	2	,,	,,	25126·0	*3849·48	3n	,,	,,	25970·2
*3976·81	6	,,	,,	25138·7	*3849·15	3n	,,	,,	25972·5
3972·85	1	1·09	,,	25163·7	*3841·42	5	,,	,,	26024·7
3971·39	6	,,	,,	25173·0	*3836·22	2	,,	,,	26060·0
*3969·89	5	,,	,,	25182·5	*3834·88	3	,,	,,	26069·1
3969·20	2	,,	,,	25186·9	3833·62	1	,,	,,	26077·7
*3963·82	5	,,	,,	25221·1	*3831·15	3	,,	,,	26094·5
3960·95	1	,,	,,	25239·4	*3830·17	5n	,,	,,	26101·2
*†3953·34	1·5	,,	7·2	25287·9	*3826·55	4n	,,	,,	26125·8
3952·56	1·5	,,	,,	25292·9	*3825·54	2n	,,	,,	26132·9

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ+	$\frac{1}{\lambda}-$				λ+	$\frac{1}{\lambda}-$	
*3823·64	2	1·06	7·3	26145·8	*3685·70	2n	1·02	7·6	27124·3
*3822·22	1	"	"	26155·5	3683·60	1·5s	"	7·7	27139·7
*3821·71	1·5	"	"	26159·0	*3681·81	1·5s	"	"	27152·9
*3821·00	1·5	"	"	26163·9	*3681·12	1	"	"	27158·1
3820·11	1	"	"	26170·0	3680·34	1	"	"	27163·7
3819·68	3	"	"	26172·9	3679·93	1·5s	"	"	27166·7
*3818·61	2	"	"	26180·2	*3679·20	1·5s	"	"	27172·1
*3817·97	1·5	"	7·4	26184·5	*3678·00	1·5	"	"	27181·0
3816·30	2	1·05	"	26196·0	*†3668·17	1·5s	"	"	27253·9
*3815·53	3	"	"	26201·3	3666·78	2	"	"	27264·2
3814·74	2	"	"	26206·7	3666·30	1s	"	"	27267·8
*3812·37	2	"	"	26223·0	3666·10	1·5s	"	"	27269·2
*3808·06	2	"	"	26252·7	*3663·35	3	"	"	27289·7
*3806·97	2	"	"	26260·2	*3662·97	1·5	"	"	27292·6
3806·68	1·5	"	"	26262·2	*3656·36	4	1·01	"	27341·9
*3804·91	4	"	"	26274·4	*3654·05	3	"	"	27359·2
*3797·85	4	"	"	26323·3	*3649·97	1	"	"	27389·8
*3797·28	2	"	"	26327·2	*3649·12	4	"	"	27396·2
*3794·75	2	"	"	26344·8	*3648·65	1·5	"	"	27399·7
3794·02	2	"	"	26349·9	*3646·26	1·5	"	"	27417·7
*3793·46	2	"	"	26353·8	*3641·95	4	"	"	27449·1
*3792·30	2	"	"	26361·8	*3641·61	2	"	"	27452·7
*3791·51	2	"	"	26367·3	*3639·93	5	"	"	27465·4
*3790·61	2	"	"	26373·6	*3636·72	3	"	7·8	27489·5
*3790·36	1·5	"	"	26375·3	3635·37	1	"	"	27499·7
3789·87	1·5	"	"	26378·7	*3635·09	1	"	"	27501·8
*3789·00	2	"	"	26384·8	*3632·92	2	"	"	27518·3
3786·38	1	"	"	26403·1	*3615·76	1·5	1·00	"	27648·9
*3769·13	1	1·04	7·5	26523·8	3613·78	1·5	"	"	27664·1
*3768·85	2s	"	"	26525·8	3612·70	1·5s	"	"	27672·3
*3768·37	3s	"	"	26529·2	3610·17	1·5	"	"	27691·7
3768·23	1·5	"	"	26530·2	*3609·62	1·5	"	"	27695·9
3767·56	1·5	"	"	26534·9	3608·52	1·5	"	"	27704·4
*3758·14	2	"	"	26601·4	*3605·46	10nr	"	"	27727·9
*3757·80	3	"	"	26603·8	3603·86	2n	"	"	27740·2
*3757·28	1·5	"	"	26607·5	†3602·68	1	"	"	27749·3
3755·97	1	"	"	26616·8	*3601·76	3	"	"	27756·4
*3749·13	4	"	"	26665·4	*3599·51	1	"	"	27773·8
*3748·73	2	"	"	26668·2	*3593·57	10nr	"	7·9	27819·7
*3747·40	1·5	"	"	26677·7	3584·45	3b	"	"	27890·5
*3744·63	2	"	"	26697·4	*3582·74	1·5	"	"	27903·8
*3744·01	4	"	"	26701·8	*3578·81	10nr	"	"	27934·4
*3743·67	4	"	"	26704·3	*3575·10	2	0·99	"	27963·3
*3743·08	2	"	"	26708·5	*3574·93	3	"	"	27964·7
*3732·15	2	1·03	"	26786·7	*3574·19	2	"	"	27970·5
*3730·91	2	"	"	26795·6	3573·79	3	"	"	27973·6
*3616·65	1·5n	"	7·6	26898·4	*3572·90	2	"	"	27980·6
*3696·02	1	1·02	"	27048·5	3569·28	1	"	"	28009·0
3689·76	1·5	"	"	27094·4	*3566·23	3n	"	"	28032·9
3689·41	1·5	"	"	27097·0	3565·31	1	"	"	28040·2
*†3688·56	1·5	"	"	27103·3	*3564·87	1·5	"	"	28043·6
*3688·24	1	"	"	27105·6	3564·44	1	"	"	28047·0
*3687·65	3n	"	"	27109·9	3562·57	1	"	"	28061·7
3687·41	3n	"	"	27111·7	*3562·40	1	"	"	28063·1
*3686·95	3n	"	"	27115·1	*3559·90	1·5	"	"	28082·8

CHROMIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		λ +	$\frac{1}{\lambda}-$				λ +	$\frac{1}{\lambda}-$	
3558·74	3n	0·99	7·9	28091·9	*3481·41	1·5	0·97	8·1	28715·9
*3556·27	1	,,	,,	28111·4	*3467·86	1·5	,,	8·2	28828·0
*3555·88	1	,,	,,	28114·5	*3465·40	1·5	,,	,,	28848·5
3554·10	1	,,	,,	28128·6	*3460·60	1	,,	,,	28888·5
3552·85	2n	,,	,,	28138·5	*3455·76	1·5	0·96	,,	28929·0
*3550·73	3n	,,	8·0	28155·2	*3453·46	1·5	,,	,,	28948·3
3548·95	1·5n	,,	,,	28169·3	*3447·90	1	,,	,,	28995·0
3533·04	1	0·98	,,	28296·2	*3447·55	1·5	,,	,,	28997·9
*3527·22	1	,,	,,	28342·9	*3447·15	1	,,	,,	29001·3
*3511·93	1	,,	,,	28466·4	*3445·71	1·5	,,	,,	29013·4
3510·66	1·5	,,	8·1	28478·6	*3441·56	1·5	,,	,,	29048·4
*3495·08	1·5	0·97	,,	28603·5	*3436·31	1·5	,,	,,	29092·8
*3488·60	1	,,	,,	28656·2	*3433·72	1·5	,,	,,	29114·7
*3483·92	1	,,	,,	28695·7	*3433·42	1	,,	,,	29117·3
*3481·66	1·5	,,	,,	28713·8					

Rowland's Normal Lines: 5798·09, 5754·89, 5731·98, 5709·69, 5688·43, 5662·75, 5634·16, 5487·96, 5447·12, 5409·99, 5379·77, 5353·59, 5324·37, 5296·88, 5266·73, 5238·12, 5202·49, 5173·91, 5146·67, 5126·37, 5090·96, 5083·53, 5050·01, 5020·20, 4994·31, 4981·90, 4934·24, 4890·94, 4859·93, 4824·31, 4805·25, 4754·22, 4727·62, 4703·98, 4690·32, 4668·30, 4643·64, 4629·50, 4611·44, 4590·12, 4571·27, 4563·94, 4508·45, 4494·72, 4447·90, 4407·85, 4376·10, 4352·91, 4318·83, 4293·25, 4267·94, 4254·49, 4222·37, 4199·25, 4185·05, 4157·94, 4121·96, 4103·10, 4083·75, 4055·69, 4029·79, 4003·91, 3977·89, 3954·00, 3926 13, 3916·88, 3897·60, 3875·24, 3843·40, 3821·32, 3794·02, 3770·12, 3754·65, 3732·54, 3695·19, 3667·40, 3640·53, 3612·21, 3583·48, 3564·68, 3540·27, 3518·48, 3491·47, 3464·61, 3455·38.

562 chromium lines coincide with solar lines, and 199 lines have, apparently, no corresponding solar lines. Their intensities are shown in the following Table :—

Intensity	Number of Lines	
	Coincident	Not Coincident
1 to 2	213	129
2 to 4	228	62
4 to 6	74	8
6 to 8	31	0
8 to 10	16	0

POTASSIUM.

Eder and Valenta: ‘Sitzber. kais. Akad. Wien,’ Bd. lx. 1893.

Flame-spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-lengths					
Lecoq de Boisbaudran	Eder and Valenta		$\lambda+$	$\frac{1}{\lambda}-$	
7697	7699	10s	2·08	3·5	12985
7663	7666	10s	,,	,,	13041
7248–6825	7040	1b	1·91	3·8	14201
5831	5832	5s	1·59	4·7	17142
5803	5802	8s	1·58	,,	17231
5783	5783	5s	,,	,,	17287
5342	5344	4n	1·46	5·1	18607
5104	5103	3n	1·40	5·4	19591
4948	4950	3n	1·35	5·5	20196
4045	4045·8	10	1·11	7·0	24710
—	3447·2	4	0·96	8·2	29001
—	3217·5	1	0·90	8·8	31071

NOTE.—The continuous spectrum due to potassium extends from 6400 to 4000, being most intense between 5700 and 4700. According to Vogel (‘Spectral Analyse’) it is due to potassium oxide, but it is present in the spark spectrum of metallic potassium in an atmosphere of hydrogen. The lines 4045·8, 3447·2 and 3217·5 occur in the arc spectrum as the double lines $\left.\begin{matrix}4047\cdot4\\4044\cdot3\end{matrix}\right\}$ $\left.\begin{matrix}3447\cdot5\\3446\cdot4\end{matrix}\right\}$ and $\left.\begin{matrix}3217\cdot8\\3217\cdot3\end{matrix}\right\}$.

SODIUM.

Eder and Valenta: ‘Sitzber. kais. Akad. Wien,’ Bk. lx. 1893.

Flame Spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Eder and Valenta)		$\lambda+$	$\frac{1}{\lambda}-$	
(5896·16)	10	1·61	4·6	16955·6
(5890·19)	10	1·60	,,	16972·8
3302·5	8	0·93	8·6	30271
2853·0	2	0·81	10·1	35041

The line 3302·5 appears in the arc spectrum as the double line $\left.\begin{matrix}3303\cdot07\\3302\cdot47\end{matrix}\right\}$, and the line 2853·0 as 2852·91.—Kayser and Runge.

LITHIUM.

Eder and Valenta: ‘Sitzber. kais. Akad. Wien,’ Bk. lx. 1893.

Flame-spectrum	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-length (Eder and Valenta)		$\lambda+$	$\frac{1}{\lambda}-$	
(6708·2)	10	1·82	4·0	14903·1
(6103·77)	3	1·66	4·4	16378·9
*4602·4	2	1·26	6·0	21722
*3232·8	4	0·91	8·8	30924

* In the arc spectrum Kayser and Runge obtain for these lines the numbers 4602·37 (21721·8) and 3232·77 (30923·7).

CALCIUM CHLORIDE AND OXIDE.

Eder and Valenta: 'Sitzber. kais. Akad. Wien,' Bk. lx. 1893.

Flame-spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-lengths					
Lecoq de Boisbaudran	Eder and Valenta		λ +	$\frac{1}{\lambda}$ −	
ε6441	†6442	4	1·75	4·2	15519
6348	*6349	2	1·73	4·3	15746
6320	*6322	2	1·72	„	15813
α { 6265	†6265	10	1·70	„	15957
6202	*6202	10	1·69	4·4	16119
6181	*6183	10	1·68	„	16169
δ { 6068	*6069	5	1·65	4·5	16473
6044	*6044	5	„	„	16541
5982	†5983	5	1·63	„	16709
γ5933	*5934	8	1·62	4·6	16847
ζ5817	*5816	3	1·58	4·7	17189
5728	†5727	2	1·56	„	17456
5644	†5644	2	1·54	4·8	17713
β { 5543	†5543·5	8	„	4·9	18034
5517	†5517	8	1·51	„	18121
5427	†5428	2	1·48	5·0	18418
5372	†5374	2	1·47	5·1	18603
	†4550	1	1·25	6·1	21972
	†4515	1	1·24	„	22142
	†4465	1	1·22	6·2	22390
	†4435	1	„	„	22542
	†4396	1	1·21	6·3	22742
	†4362	1	1·20	6·4	22919
	†4324	1	1·19	„	23120
	†4294	1	1·18	6·5	23282
	†4257	1	1·17	„	23484
4226	4227	10s	1·16	6·6	23651
	†4159	1	1·14	6·7	24037
	†4122	1	1·13	6·8	24253
	†4084	1	1·12	6·9	24479
	†4042	1	1·11	7·0	24733
	†4002	1	1·10	7.1	24980
	†3972	1	1·09	„	25169
	†3942	1	„	7·2	25361
	†3909	1	1·08	7·3	25574
	†3880	1	1·07	„	25766
	†3840	1	1·06	„	26034
	†3815	1	1·05	7·4	26205
	†3771	1	1·04	7·5	26511
	†3722	1	1·03	7·6	26860
	†3687	1	1·02	„	27115
	†3644	1	1·01	7·7	27435
	†3608	1	1·00	7·8	27708
	†3569	1	0·99	7·9	28011
	†3531	1	0·98	8·0	28313
	†3494	1	0·97	8·1	28612
	†3463	1	„	8·2	28868
	†3429	1	0·96	8·3	29155

In the arc spectrum Kayser and Runge obtain for the line 4227, due to metallic calcium, the number 4226·91 (23650·4.)

* Due to calcium chloride.

† Due to calcium oxide.

STRONTIUM CHLORIDE AND OXIDE.

Eder and Valenta: 'Sitzber. kais. Akad. Wien,' Bk. lx. 1893.

Flame-spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-lengths					
Lecoq de Boisbaudran	Eder and Valenta		λ+	$\frac{1}{\lambda}$−	
ζ 6862	†6863	4	1·86	3·9	14567
6827	†6828	4	1·85	4·0	14642
6729	*6731	1	1·83	„	14853
γ 6694	†6695	8	1·82	„	14932
6664	†6665	8	1·81	4·1	15000
ε 6627	†6628	6	1·80	„	15083
6597	*6597	6	1·79	„	15154
δ 6464	†6464	6	1·76	4·2	15466
η 6350	*6351	5	1·73	4·3	15741
6276	†6275	1	1·71	„	15932
6233	†6233	1	1·70	„	16039
6191	†6192	1	1·68	4·4	16145
α 6059	†6060	10	1·65	4·5	16497
6031	†6032	10	1·64	„	16574
5970	(5968)	2s	1·63	„	16751
5940	†5940	1	1·62	4·6	16830
ι 5911	†5910	3	1·61	„	16916
5890	†5891	3	1·60	„	16970
β 4607	(4608)	10s	1·26	6·0	21695
	†4505	1	1·23	6·1	22191
	†4470	1	„	6·2	22365
	†4430	1	1·21	6·3	22567
	†4391	1	1·20	„	22768
	†4357	1	„	6·4	22945
	†4328	1	1·19	„	23099
	†4292	1	1·18	6·5	23293
	†4259	1	1·17	„	23473
	(4032)	2s	1·11	7·0	24795
	3806	2b	1·05	7·4	26267
	3778	2b	„	„	26462
	3738	2b	1·04	7·5	26745
	3692	3b	1·02	7·6	27078
	3647	3b	1·01	7·7	27412
	3612	1n	1·00	7·8	27678

In the arc spectrum Kayser and Runge obtain for the lines 5968, 4608, and 4032, due to metallic strontium, the numbers 5970·38 (16744·8) 4607·52 (21697·6) and 4032·51 (24791·4).

* Due to strontium chloride.

† Due to strontium oxide.

BARIUM OXIDE AND CHLORIDE.

Eder and Valenta: 'Sitzber. kais. Akad. Wien,' Bk. lx. 1893.

Flame-spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-lengths					
Lecoq de Boisbaudran	Eder and Valenta		λ +	1/λ −	
6819	†6820	1	1·85	4·0	14659
6499	6497	2	1·77	4·2	15387
6448	†6450	1	1·75	,,	15500
6297	†6297	2	1·71	4·3	15876
6239	†6240	4	1·70	,,	16021
6178	†6177	4	1·68	4·4	16185
6108	†6109	4	1·66	,,	16365
6044	†6044	4	1·65	4·5	16541
5995	†5997	1	1·63	,,	16670
5938	†5938	8	1·62	4·6	16836
5881	†5882	8	1·60	,,	16996
5824	†5827	1	1·59	4·7	17157
5768	†5768	4	1·57	,,	17332
5719	†5720	6	1·56	4·8	17478
5661	†5660	8	1·54	,,	17663
5613	†5612	3	1·53	,,	17814
5536	5536	10	1·51	4·9	18059
5492	†5493	8	1·50	5·0	18200
5461	†5460	1	1·49	,,	18310
5346	†5346	9	1·46	5·1	18700
	†5316	1	1·45	,,	18806
5314	*5314	2	,,	,,	18813
	†5280	1	1·44	5·2	18934
	†5255	1	,,	,,	19024
5242	*5243	2	1·43	,,	19068
5215	†5215	8	,,	,,	19170
5089	†5089	9	1·39	5·4	19645
5019	†5022	2	1·37	5·5	19907
4974	†4977	2	1·36	,,	20087
	†4954	1	,,	,,	20180
4873	†4873·5	10	1·33	5·6	20513
4794	†4796	3	1·31	5·7	20845
	†4756	1	1·30	5·8	21020
	†4736	1	,,	,,	21109
	† 4694	3	1·29	5·9	21498
	4681	2	1·28	,,	21351
	† 4644	1	1·27	,,	21527
	4630	1	,,	6·0	21592
	† 4589	1	1·26	,,	21785
	4567	1	1·25	,,	21890
	†4554 (?)	1	,,	6·1	21953
	†4535	1	1·24	,,	22045
	†4488	1	1·23	6·2	22275
	†4443	1	1·22	,,	22501
	†4398	1	1·21	6·3	22731
	†4353	1	1·19	6·4	22966
	†4309	1	1·18	6·5	23201
	†4270	1	1·17	,,	23413
	†4235	1	1·16	6·6	23606
	†4200	1	1·15	6·7	23803
	†4165	1	1·14	,,	24003
	†4128	1	1·13	6·8	24218

BARIUM OXIDE AND CHLORIDE—*continued.*

Flame-spectrum		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Wave-lengths					
Lecoq de Boisbaudran	Eder and Valenta		$\lambda +$	$\frac{1}{\lambda} -$	
	†4088	1	1·12	6·9	24455
	†4047	1	1·11	7·0	24703
	†4009	1	1·10	„	24937
	†3984	1	„	7·1	25093
	†3951	1	1·09	7·2	25303
	†3918	1	1·08	„	25516

In the arc spectrum Kayser and Runge have obtained for the lines 6497, 5536, and 4554, due to metallic barium, the numbers 6498·93 (15382·9), 5535·69 (18069.7), and 4554·21 (21951·6).

* Due to barium chloride.
† Due to barium oxide.

BORON (SPARK SPECTRUM).

Eder and Valenta: 'Denkschr. math. Wissensch. kais. Akad. Wien,' Bd. lx. 1893.
Ciamician: 'Sitzber. kais. Akad. Wissensch. Wien,' Bd. lxxxix. 1890.

Wave-lengths		Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Ciamician	Eder and Valenta		$\lambda +$	$\frac{1}{\lambda} -$	
5103		1	1·40	5·4	19590·9
4981		1	1·36	5·5	20070·8
4966		1	„	„	20131·4
4964		1	„	„	20139·5
	3957·9	2	1·09	7·1	25258·8
	3941·7	2	„	7·2	25362·6
	3829·3	1	1·06	7·3	26107·3
	3824·5	1	„	„	26140·0
	*3451·3	6	0·96	8·2	28968·4
	3246·9	1	0·91	8·8	30789·8
	2689·0	1	0·77	10·8	37177·8
	2686·2	1	„	„	37216·5
	*2497·7	10	0·73	11·7	40025·1
	*2496·8	10	„	„	40039·6
	2388·5	1	0·71	12·4	41854·9
	2267·0	2	0·68	13·3	44097·9
	2266·4	2	„	„	44109·5
	2088·8	2	0·65	14·9	47859·5
	2088·4	2	„	„	47868·6
	2066·2	2	0·64	15·3	48382·7
	2064·6	2	„	„	48416·2

* Observed also by Hartley.

TIN (ARC SPECTRUM).

Kayser and Runge: ‘Abhandl. königl. Akad. Wissensch. zu Berlin,’ 1893.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}$−	
5631·91	0·03	8	5630·0 Thalén	1·54	4·8	17751·2
4524·92	0·03	8	4524·0 „	1·24	6·1	22093·7
3801·16	0·05	6r	3800·3 H. & A.	1·05	7·4	26300·4
†3655·88	0·03	4	3655·5 „	1·01	7·7	27345·5
3330·71	0·05	6r	3330·0 „ 3326·0 L.&D.	0·93	8·5	30015·1
‡3262·44	0·03	8r	3261·6 „ 3260·0 „	0·92	8·7	30643·2
3218·78	0·03	4	3218·0 „	0·90	8·8	31058·9
3175·12	0·03	8r	3174·3 „ 3175·0 „	0·89	9·0	31485·9
3141·92	0·03	4	3140·6 „ 3141·7 „	0·88	9·1	31818·6
3034·21	0·03	10r	3033·1 „ 3033·0 „	0·86	9·4	32948·1
§3032·88	0·03	4r		„	„	32962·6
3009·24	0·05	10r	3007·9 „ 3008·5 „	0·85	9·5	33221·5
2922·48	0·15	$2b^v$		0·83	9·8	34207·7
¶2913·67	0·03	6r	2911·9 „ 2913·1 „	„	9·9	34311·1
2863·41	0·03	10r	2862·1 „ 2862·8 „	0·81	10·1	34913·3
2850·72	0·03	6r	2849·3 „	„	„	35068·8
2840·06	0·03	10r	2838·9 „ 2839·5 „	„	10·2	35200·3
2813·66	0·05	4r	2812·5 „ 2813·5 „	0·80	10·3	35530·6
2812·70	0·05	4	2811·5 „ 2812·5 „	„	„	35542·7
2788·09	0·10	6br	2787·3 „ 2787·5 „	„	10·4	35856·4
**2785·14	0·03	4r	2784·0 „ 2784·7 „	„	„	35894·4
††2779·92	0·03	6r	2778·8 „ 2779·5 „	0·79	„	35961·9
2706·61	0·03	10r	2705·8 „	0·78	10·7	36935·9
2661·35	0·03	6r	2660·2 „ 2660·7 „	0·77	10·9	37564·0
2637·05	0·03	4n	2636·5 „	0·76	11·0	37910·2
2594·49	0·03	6r	2593·6 „ 2593·5 „	0·75	11·2	38532·0
2571·67	0·03	8r	2570·5 „ 2571·0 „	„	11·3	38873·9
‡‡2558·12	0·20	$6b^v$	2557·7 „ 2557·5 „	0·74	11·4	39079·8
2546·63	0·03	8r	2545·6 „ 2546·1 „	„	11·5	39256·1
2531·35	0·10	$6b^v$	2530·8 „ 2530·7 „	„	„	39493·1
2526·13	0·10	$1b^v$		„	11·6	39574·6
§§2524·05	0·05	4r	2523·4 „ 2523·5 „	„	„	39607·3
2499·30	0·20	$1b^v$	2499·3 „	0·73	11·7	39999·5
2495·80	0·03	8r	2495·0 „ 2493·5 „	0·73	11·7	40055·6
2491·91	0·20	$2b^v$	2488·0 „ 2493·5 „	„	11·8	40118·1
2483·50	0·03	8r	2482·9 „ 2483·1 „	„	„	40254·0
2455·30	0·03	4	2455·5 „	0·72	12·0	40716·2
2433·53	0·03	2	2433·3 „	„	12·1	41080·5
2429·58	0·03	10r	2429·3 „ 2439·5 „	„	„	41147·3
2421·78	0·03	10r	2421·8 „ 2421·5 „	0·71	12·2	41279·7
2408·27	0·03	6r	2408·0 „ 2407·9 „	„	12·3	41511·3
2386·96	0·50	2n		„	12·4	41881·5
2380·82	0·05	4r	2381·1 „	„	12·5	41989·8
2364·89	0·20	2n	2364·7 „	0·70	12·6	42272·7
2358·05	0·05	4	2357·7 „	„	„	42395·3
2354·94	0·03	10r	2355·0 „ 2354·5 „	„	„	42451·3
2334·89	0·03	8r	2335·3 „ 2334·3 „	„	12·8	42815·8
2317·32	0·03	10r	2317·9 „ 2317·0 „	0·69	12·9	43140·4
2286·79	0·03	6r	2288·1 „ 2286·9 „	„	13·2	43716·2
2282·40	0·03	4	2282·5 „	„	„	43800·3
2269·03	0·05	10r	2270·0 „ 2275·4 ? „	0·68	13·3	44058·4
2267·30	0·05	6r	2268·6 „	„	„	44092·0

TIN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}-$	
2251·29	0·10	6r	2251·0 „	0·68	13·4	44405·6
2246·15	0·10	10r	2247·0 H.&A. 2245·8 L.&D.	„	13·5	44507·1
2231·80	0·10	6r	2233·2 „ 2231·3 „	„	13·6	44793·3
2209·78	0·10	10r	2210·1 „ 2210·7 „	0·67	13·8	45239·6
2199·46	0·10	10r	2199·2 „ 2198·7 „	„	13·9	45451·8
2194·63	0·10	8r	2195·0 „ 2194·1 „	„	„	45551·9
2171·5	0·20	6r		0·66	14·1	46037·0
2151·2	0·20	6r?	2151·2	„	14·3	46471·4
2148·7	0·20	8r?		„	„	46525·5
2141·1	0·20	10r		„	14·4	46690·6
2121·5	0·20	6r	2119·2 ?	0·65	14·6	47121·9
2113·9	0·30	6r	2113·6	„	14·7	47291·2
2100·9	0·50	6r		„	14·8	47583·8
2096·4	0·30	10r		„	„	47686·0
2091·7	0·50	6r?		0·65	14·9	47793·1
2080·2	0·50	6	2079·3 „	„	15·3	48057·0
2073·0	0·50	8r		0·64	„	48224·0
2068·7	0·50	6	2066·1 ? „	„	„	48324·2
2063·8	0·50	6		„	„	48439·0
2058·3	0·50	6		„	„	48568·5
2053·8	0·50	6		„	„	48674·9

* See Iron. † See Copper. ‡ See Lead. § See Arsenic.
¶ See Gold. ** See Barium. †† See Magnesium.
‡‡ See Zinc. §§ See Silicon.

LEAD (ARC SPECTRUM).

Kayser and Runge: 'Abhandl. königl. Akad. Wissench. zu Berlin,' 1893.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}-$	
6002·08	0·10	2b^v	6001·5 Thalén	1·63	4·5	16656·4
5201·65	0·05	4b^v	5201·0 „	1·42	5.3	19219·4
5005·62	0·05	6b^v	[5005·634 Rowland]	1·37	5·5	19972·1
4340·65	0·05	2		1·19	6·4	23031·6
4168·21	0·03	4r	4167·5 Thalén	1·14	6·7	23984·4
4062·30	0·03	4r	4061·5 H. & A.	1·12	6·9	24609·7
4057·97	0·03	10r	4057·6 „	„	„	24636·0
4019 77	0·05	4r	4020·5 „ 4019·0 L.&D.	1·11	7·0	24870·0
3740·10	0·03	8r	3738·9 „ 3739·3 „	1·04	7·5	26729·7
3683·60	0·03	10r	[3683·622 Rowland]	1·02	7·7	27139·7
3671·65	0·03	4r	3671·0 H.&A. 3670·7 „	„	„	27228·0
3639·71	0·03	10r	[3639·728 Rowland]	1·01	„	27467·0
3572·88	0·03	8r	3572·6 H.&A. 3572·0 „	0·99	7·9	27980·7

LEAD (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ +	$\frac{1}{\lambda}$ −	
*†3262·47	0·05	6	3260·0 L.&D.	0·92	8·7	30643·2
3240·31	0·05	6	3238·6 „	0·91	8·8	30852·4
3220·68	0·05	6	3219·9 H. & A. 3219·6 „	0·90	„	31040·5
3150·9	2·00	4n		0·89	9·0	31728·0
3119·09	0·10	2	3118·5 „	0·88	9·1	32051·5
2980·29	0·10	2	2981·0 „	0·84	9·6	33544·2
2926·84	0·10	2b^{v}		0·83	9·8	34156·7
2873·40	0·03	6r	2872·2 „ 2872·0 „	0·82	10·0	34792·0
2833·17	0·03	10r	2832·2 „ 2832·9 „	0·81	10·2	35286·0
2823·28	0·03	6r	2822·1 „ 2822·5 „	0·80	10·3	35409·5
2802·09	0·03	8r	2801·4 „ 2801·1 „	„	„	35677·4
‖§2712·62	0·10	2b^{v}		0·78	10·7	36854·0
2697·72	0·10	6rn	2697·2 „ 2697·0 „	0·77	10·8	37057·5
2663 26	0·03	6r	2662·5 „ 2662·7 „	„	10·9	37537·1
2657·16	0·03	2		„	„	37623·3
2650·77	1·00	8n	2650·0 „ 2650·5 „	0·76	11·0	37713·9
¶2628·36	0·03	2r	2627·4 „ 2627·8 „	„	11·1	38035·4
2614·26	0·03	8r	2613·4 „ 2613·7 „	„	„	38240·6
2613·74	0·03	4r		0·76	11·1	38248·3
2577·35	0·05	6r	2576·4 „ 2575·7 „	0·75	11·3	38788·2
2476·48	0·03	6r	2475·7 „ 2476·5 „	0·73	11·9	40368·0
2446·28	0·03	6r	2445·7 „ 2446·1 „	0·72	12·0	40866·3
**2443·92	0·03	6r	2443·6 „ 2443·7 „	„	„	40905·9
2428·71	0·05	6r	2427·8 „ 2428·5 „	„	12·1	41162·0
2411·80	0·03	6r	2411·2 „ 2411·5 „	0·71	12·3	41450·5
2402·04	0·03	6r	2402·1 „ 2401·8 „	„	„	41619·0
††2399·69	0·03	4r	2399·4 „	„	„	41659·7
2393·89	0·03	8r	2393·7 „ 2393·7 „	„	12·4	41760·6
2388·89	0·05	4r	2389·0 „ 2388·8 „	„	„	41848·0
2332·54	0·03	6r	2333·3 „ 2332·0 „	0·70	12·8	42858·9
2257·53	0·15	1		0·68	13·4	44282·8
2254·02	0·05	4r		„	„	44351·8
2247·00	0·05	10r	2247·9 „	„	13·5	44490·3
2237·52	0·05	8r	2238·2 „	„	13·6	44678·7
§§2203·57	0·05	4	2204·3 „	0·67	13·9	45367·0
2187·99	0·10	2		„	14·0	45690·0
***2175·88	0·10	6r		0·66	14·1	45944·3
2170·07	0·10	10r	2170·0 „	„	14·2	46067·3
2115·1	0·10	8r		0·65	14·7	47264·4
2112·0	0·10	6		„	„	47333·8
2088·5	0·10	8r		„	14·9	47866·3

* See Tin. † See Lead. ‖ See Zinc. § See Cadmium.
¶ See Iron. ** See Thallium. †† See Mercury.
§§ Possibly not due to Lead. *** See Antimony.

ARSENIC.

Kayser and Runge: 'Abhandl. königl. Akad. Wissensch. zu Berlin,' 1893.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}-$	
3119·69	0·03	4	3119·2 H. & A.	0·88	9·1	32045·4
3075·44	0·03	2	3075·0 „	0·87	9·3	32506·4
*3032·96	0·03	4	3032·2 „	0·86	9·4	32961·7
2991·11	0·03	2	2990·2 „	0·85	9·6	33422·8
2898·83	0·03	4r	2898·2 „	0·82	9·9	34486·8
2860·54	0·03	6r	2859·7 „	0·81	10·1	34948·3
2780·30	0·03	8r	2779·5 „	0·79	10·4	35956·9
2745·09	0·03	6r	2744·1 „	„	10·6	36418·1
2492·98	0·03	1	2491·9 „	0·73	11·8	40100·8
2456·61	0·03	4r	2456·2 „	0·72	12·0	40694·5
2437·30	0·03	1	2436·9 „	„	12·1	41016·9
2381·28	0·03	4r	2381·0 „	0·71	12·5	41981·7
2370·85	0·03	4r	2370·8 „	0·70	„	42166·5
2369·75	0·03	4r	2369·7 „	„	„	42186·0
2363·12	0·03	2	2362·8 „	„	12·6	42304·3
2349·92	0·03	10r	2350·1 „	„	12·7	42541·9
†2288·19	0·03	10r	2288·9 „	0·69	13·2	43689·5
2271·46	0·05	4	2272·3 „	0·68	13·3	44011·2
2266·79	0·05	4	2267·5 „	„	„	44101·9
2228·77	0·05	2	2230·0 „	0·67	13·6	44854·2
2206·08	0·10	2	2207·0 „	„	13·8	45315·5
2205·28	0·10	2		„	„	45331·9
2183·07	0·10	1	2182·3 „	„	14·0	45793·0
2176·37	0·10	1	2176·8 „	0·66	14·1	45934·0
2165·64	0·10	4	2165·4 „	„	14·2	46161·5
2144·21	0·10	4	2144·5 „	„	14·4	46622·8
2133·92	0·10	2	2135·2 „	„	14·5	46847·6
2113·14	0·10	2	2112·2 „	0·65	14·7	47308·2
2089·71	0·10			„	14·9	47838·6
2089·02	0·10			„	„	47854·4
2069·96	0·10			0·64	15·3	48294·8
2067·26	0·10			„	„	48357·9
2065·52	0·10			„	„	48398·7
2010·23	0·20			0·63	15·7	49729·8
†2009·31	0·20			„	„	49752·6

* See Tin.

† The spectrum of arsenic shows no lines in the visible spectrum, but between 3000–2000, the lines of arsenic, and in particular 2288·19 and 2009·31, constantly appear as impurities in other metals and in the carbon poles. The lines 2288·19 and 2009·31, given as copper lines (*Report*, 1893, pp. 397, 398), appear to be due to arsenic. The *spark*-spectrum of arsenic, on the other hand, shows some fifty lines in the visible portion.

ANTIMONY (ARC SPECTRUM).

Kayser and Runge: 'Abhandl. königl. Akad. Wissensch. zu Berlin,' 1893.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)		Reduction to Vacuum		Oscillation Frequency in Vacuo
					λ+	$\frac{1}{\lambda}-$	
*5730·52	0·20	2b^v			1·56	4·7	17445·7
*5707·63	0·20	1n			„	4·8	17515·6
*5660·98	0·20	1n			1·54	„	17660·0
*5632·22	0·20	4b^v			„	„	17750·2
*5568·25	0·20	1n	5567·0 Thalén		1·52	4·9	17954·1
*5556·39	0·20	2n			„	„	17992·4
*5490·60	0·30	2			1·50	5·0	18207·9
4033·70	0·03	4		4032·0 L.& D.	1·11	7·0	24784 1
3722·92	0·03	4	3722·4 H.&'A.		1·03	7·6	26853·0
3637·94	0·03	4	3637·5 „	3637·0 „	1·01	7·8	27480·3
3383·24	0·03	2	3382·0		0 95	8·4	29549·1
3267·60	0·03	6r	3267·6 „	3265·0 „	0·92	8·7	30594·8
3232·61	0·03	6r	3231·6 „	3230·8 „	0·91	8·8	30926·0
3029·91	0·03	6r	3029·0 „	3028·0 „	0·86	9·4	32994·9
2878·01	0·03	10r	2877·1 „	2876·5 „	0·82	10·0	34736·2
2851·20	0·03	2	2849·9 ?		0·81	10·1	35062·8
2770·04	0·03	8r	2768·9 „		0·79	10·5	36090·1
2727 32	0 03	4	2726·1 „		0·78	10·6	36655·4
2719·00	0·03	4r	2717·9 „		„	10·7	36767·5
2692·35	0·03	4r	2691·3 „		0·77	10·8	37131·5
2682·86	0·03	4r	2681·7 „		„	„	37262·9
†2670·73	0·03	6r	2668·9 „		„	10·9	37432·0
2652·70	0·03	4	2651·7 „		0·76	11·0	37686·4
2614·74	0·03	2	2613·7 „		„	11·1	38233·6
2612·40	0·03	4r	2611·3 „		„	„	38267·9
2598·16	0·03	10r	2597·2 „	2597 5	0·75	11·2	38477·6
2574·14	0·03	2	2572·7 „		„	11·3	38836·6
2554·72	0·03	2	2553·3 „		0·74	11·4	39131·8
‡2528·60	0·03	10r	2527·6 „	2528·0 „	„	11·6	39536·0
2514·64	0·03	1	2514·5 „		0·73	„	39755·5
§2510·60	0·03	1	2509·5 „		„	11·7	39819·4
2481·81	0·03	1	2480·4 „		„	11·8	40281·4
2480·50	0·03	2	2479·4 „		„	„	40302·6
2474·63	0·03	2	2473·4 „		0·73	11·9	40398 3
2445·59	0·03	4r	2444·8 „		0·72	12·0	40877·6
2426·44	0·03	4r	2425·7 „	2426·0 „	„	12·2	41200·4
2422·21	0·03	4	2421·5 „		„	„	41272·4
2395·31	0·03	2	2395·3 „		0·71	12·4	41735·8
2383·71	0·03	4	2383·2 „	2383·3 „	„	„	41939·0
‖2373·78	0·05	6	2374·3 „		0·70	12·5	42114·4
2360·60	0·03	2	2361·3 „		„	12·6	42349·5
2352·31	0·03	2	2353 0 „		„	12·7	42498·7
2329·19	0·03	2	2329·7 „		„	12·8	42920·6
2311·60	0·03	10r	2311·8 „	2313·0 „	0·69	13·0	43247·1
2306·56	0·03	8r	2306·8 „	2310·0 „	„	„	43341·6
2293·54	0·10	4	2294·0 „		„	13·1	43587·6
2289·09	0·10	4	2288·8 „		„	„	43672·4
2262·55	0·20	6	2263·5 „		0·68	13·4	44184·5
2225·06	0·10	4	2226·3 „		0·67	13·7	44928·9
2222·10	0·10	4	2223·5 „		„	„	44988·8
2220·85	0·10	2	2221·5 „		„	„	45014·1
2212·54	0·10	1	2211·3 „		„	13·8	45183·1
2208·65	0·10	4	2209·0 „		„	„	45262·7

ANTIMONY (ARC SPECTRUM)—*continued.*

Wave-length	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda}$	Oscillation Frequency in Vacuo
2207·86	0·10	2		0·67	13· 8	45278·9
2203·83	0·10	2	2203·8 H. & A.	„	„	45361·7
2203·13	0·10	2	2202·2 „	„	13·9	45376·1
2201·46	0·10	4	2200·3 „	„	„	45410·5
¶2179·33	0·10	6r	2179·0 „	0·66	14·1	45871·6
**2175·99	0·10	10r	2175·8 „	„	„	45942·0
2159·32	0·20	4	2159·4 „	„	14·3	46296·6
2159·02	0·20	4		„	„	46303·0
2145·10	0·20	4	2144·4 „	„	14·4	46603·5
2141·76	0·20	4	2142·0 „	„	„	46676·2
2139·89	0·20	4	2139·3 „	„	„	46717·0
2137·21	0·20	4	2135·7 „	„	14·5	46775·5
2127·55	0·20	4	2126·1 „	0·65	„	46987·9
2117·28	0·30	4	2118·0 „	„	14·6	47215·8
2098·47	0·30	6	2096·4 „	„	14·8	47639·0
2079·55	0·30	4	2075·3 „	„	15·3	48072·0
††2068·54	0·30	10r	2064·8 „	0·64	„	48328·0

* Possibly not due to Antimony. † See Zinc.
‡ See Silicon. § See Gold. ‖ See Iron.
¶ See Copper. ** See Lead. †† See Tin.

BISMUTH (ARC SPECTRUM).

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
5742·74	0·20	$4b^v$		1·57	4·7	17408·6
5552·44	0·20	$8b^v$	5553·0 Thalén	1·51	4·9	18005·2
5298·52	0·20	$2b^v$		1·45	5·2	18868·0
4733·91	0·20	$4b^v$		1·30	5·8	21118·4
4722·72	0·03	10r	4722·0 „	1·29	„	21168·4
4692·45	0·03	1	4691·5 „	1·28	5·9	21304·9
4615·71	0·03	1		1·26	6·0	21659·1
4615·27	0·03	1		„	„	21661·2
4493·16	0·03	2		1·23	6·2	22249·8
4492·79	0·03	2		„	„	22251·7
4308·70	0·03	4		1·18	6·5	23202·4
*4308·34	0·03	4		„	„	23204·3
4254·33	0·03	1n		1·17	„	23499·0
4122·01	0·03	6	4119·0 ? „	1·13	6·8	24253·2
4121·69	0·03	6		„	„	24255·1
3888·34	0·03	1		1·07	7·3	25710·6
3888·05	0·03	1		„	„	25712·5
3596·26	0·03	4r	3595·7 „ 3595·3	1·00	7·8	27798·9
3511·00	0·03	4r	3510·5 „ 3510·4	0·98	8·0	28473·9
3405·39	0·05	2r		0·95	8·3	29356·9
3397·31	0·03	4r	3396·7 „ 3396·2	„	„	29426·7
3076·73	0·03	2	3075·7 „	0·87	9·3	32492·7
3067·81	0·03	10r	3067·1 „ 3066·0	„	„	32587·2

BISMUTH (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
†3034·99	0·05	4b[*]	3034·5 Thalén	0·86	9·4	32989 6
‖3024·75	0·03	8r	3023·8 „ 3023·5	„	9·5	33051·1
2993·46	0·03	8r	2992·2 „	0·85	9·6	33396·6
2989·15	0·03	8r	2988·1 „	„	„	33444·7
2944·38	0·10	1n	2942·4 „	0·84	9·8	33953·2
§2938·41	0·03	10r	2937·5 „ 2937·4	0·83	„	34022·2
2898·08	0·03	10r	2897·2 „ 2897·0	0·82	9·9	34495·7
2892·98	0·10	1n		„	10·0	34556·4
2883·88	0·10	1n		„	„	34665·5
2863·86	0·05	4	2862·5 „ 2862 0	0·81	10·1	34907·8
2809·74	0·03	8r	2808·4 H.&A. 2810·0 L. & D.	0·80	10·3	35580·2
2798·75	0·03	4	2798·0 „ 2799·0 „	„	10·4	35719·8
2780·57	0·03	8r	2779·3 „ 2780·0 „	0·79	„	35953·4
2730·61	0·03	6r	2729·3 „ 2730·0 „	0·78	10·6	36611·2
2696·84	0·03	6r	2695·6 „	0·77	10·8	37069·6
2627·99	0·03	8r	2627·0 „	0·76	11·1	38040·8
2600·73	0·03	1		0·75	11·2	38439·5
2594·14	0·05	1		0·75	11·2	38537·2
2582·17	0·03	2	2581·5 „	„	11·3	38715·8
2532·65	0·50	4n	2531·9 „	0·74	11·5	39472·5
2524·58	0·03	8r	2523·5 „ 2524·0 „	„	11·6	39599·0
2515·72	0·03	6r	2514·3 „ 2515·4 „	0·73	„	39738·4
2499·58	0·03	2	2499·1 „	„	11·7	39995·0
2489·5	2·00	6b	2489·1 „	„	11 8	40157·2
2448·15	0·03	4	2447·2 „ 2448·0 „	0·72	12·0	40835·2
2433·5	2·00	4b	2435·5 „	„	12·1	41080·9
2430·51	0·05	2n	2429·3 ? 2431·0 „	„	„	41131·5
2409·7	2·00	2b		0·71	12·3	41486·7
2400·98	0·03	8r	2400·7 „ 2400·8 „	„	„	41637·4
2369·22	0·03	1	2368·0 „	0·70	12·5	42195·5
2360·0	1·00	1b		„	12·6	42360·4
2354·57	0·05	2n		„	12·7	42457·9
2346·0	0·50	2n	2347·0 „	„	„	42613·3
2333·87	0·05	2	2331·8 „	„	12·8	42834·5
2328·27	0·05	2	2327·0 „	„	„	42937·6
2309·4	1·00	4b[*]		0·69	13·0	43288·0
2281·39	0·10	2b	2281·0 „	„	13·2	43819·7
2276·64	0·03	8n	2276·9 „ 2277·0 „	0·68	„	43911·2
2230·70	0·05	10r	2231·4 „	„	13·6	44815·4
2228·31	0·05	8r	2229·1 „	0·67	„	44863·5
2224·27	0·05	2		„	13·7	44944·9
2214·21	0·05	4	2214·8 „	„	13·8	45149·0
2203·2	1·00	6n	2203·3 „	„	13·9	45375·1
2189 70	0·05	8r	2190·4 „	„	14·0	45654·4
2176·70	0·20	6r	2176 6 „	0·66	14·1	45927·0
2164·16	0·20	4r		„	14·2	46193·1
2157·03	0·05	10r		„	14·3	46345·7
2153·60	0·20	4r		„	„	46419·6
2152·98	0·05	8r		„	„	46433·0
2134·38	0·10	10r		„	14·5	46837·5
2133·72	0·10	8r	2133·8 „	„	„	46852·0
2110·35	0·10	10r	2109·8 „	0·65	14·7	47370·8
2061·77	0·10	10r	2058·2 „	0·64	15·3	48486·7

[*] See Strontium. † See Potassium. ‖ See Gold. § See Silver.

Isomeric Naphthalene Derivatives.—Eighth Report of the Committee, consisting of Professor W. A. TILDEN *and* Professor H. E. ARMSTRONG. *(Drawn up by* Professor ARMSTRONG.)

The Conversion of Sulphochlorides into the corresponding Chloro-derivatives.—In the case of naphthalene derivatives no interaction is of greater practical importance than that which occurs when sulphochlorides are heated with phosphorus pentachloride, whereby they are converted into chloro-derivatives. At one time it was argued that reliance could not be placed on this interaction as a means of determining constitution, but of late years no such objection has been raised, and the idea that isomeric change may attend the displacement of the sulphonic radicle by chlorine appears to have been abandoned. The results obtained, especially by Cleve and by Dr. Wynne and the writer, are so uniformly consistent *inter se* that, bearing in mind the extent of the field covered, there is no longer room for doubt. Observations made during the past year are of interest as throwing light on the nature of the interaction.

There have long been instances on record of the conversion of sulphochlorides into corresponding chloro-derivatives and sulphur dioxide ($RSO_2Cl = RCl + SO_2$) by mere distillation. The successful use recently made of this method in the writer's laboratory in preparing chloro- and bromo-derivatives of camphor by Dr. Kipping and Mr. Pope has led him and Dr. Wynne to systematically study the behaviour of naphthalene sulphochlorides, which they had long known underwent decomposition, evolving sulphur dioxide, when heated. The conclusion arrived at is that, in all probability, phosphorus pentachloride acts merely by facilitating the resolution of the sulphochloride into sulphur dioxide and the chloro-derivative by attacking the former and converting it into thionyl chloride ; and that, in fact, the chlorine in the chloro-derivative is not improbably the original chlorine of the sulphochloride and not chlorine derived from the pentachloride. In most cases the amount of chloro-derivative produced by directly distilling the sulphochloride is inferior to that obtained by means of pentachloride, as the decomposition is facilitated by the chloride, and therefore takes place at a lower temperature in its presence. There is always more or less of a resinoid condensation product formed on distilling the sulphochloride, but the amount is in some cases very small, while in others practically nothing else is obtained. On the other hand, in the case of compounds which are very readily chlorinated, the method permits of the production of chloro-derivatives corresponding to the sulphochlorides which are almost unprocurable from them by the ordinary method. For example, 1 : 1′-chloronaphthalenesulphonic chloride yields a very large proportion of 1 : 1′-dichloronaphthalene when distilled, although when heated with phosphorus pentachloride it is almost entirely converted into 1 : 4 : 1′ trichloronaphthalene. The α-sulphochlorides appear all to decompose more readily and to yield a larger proportion of chloro-derivative than do the β-sulphochlorides. It may be added that, taking into account the readiness with which change occurs during sulphonation, the non-occurrence of isomeric change on distilling sulphochlorides is probably significant.

Bromo-derivatives of Naphthalene.—The conversion of naphthalene sulphobromides into corresponding bromonaphthalenes by means of phosphorus pentabromide is attended with great difficulty, as the bromide frequently acts almost exclusively as a brominating agent, owing to the readiness with which it is resolved into the terbromide and bromine. Far better results are obtained in many cases by merely distilling the sulphobromide, although the formation of higher bromo-derivatives is not entirely avoided. During the year Mr. Jenks and the writer have made considerable progress in completing the series of bromonaphthalenes (di- and tri-derivatives), and in determining the nature of the sulphonic acids prepared from the dibromonaphthalenes by Mr. Rossiter and the writer.

One result of which mention may be made relates to the tribromonaphthalene obtained by Jolin by distilling nitro-1 : 4-dibromonaphthalene with phosphorus pentabromide, which hitherto has always been represented as the 1 : 4 : 1′ derivative, apparently because it is supposed that, as a rule, α-nitro-compounds are formed on nitrating naphthalene derivatives. Judging from the low melting-point of the tribromonaphthalene in question, it is improbable that it is a tri-α-derivative, as such a tribromonaphthalene should melt at a much higher temperature. The accuracy of this conclusion is established by the observation that 1 : 4-dibromonaphthalene *hetero*-β-sulphonic bromide is converted by distillation into a tribromonaphthalene which is undoubtedly identical with that prepared from nitro-1 : 4-dibromonaphthalene.

Attempts to devise a satisfactory method of preparing 1 : 1′-dibromonaphthalene had been made by Mr. Jenks and the writer prior to Meldola's discovery of this modification, and as these have been continued to a successful issue reference may be made to the subject. The first method devised involved brominating the acetyl derivative of Guareschi's 1 : 4′ bromonaphthylamine, prepared by brominating nitronaphthalene, &c.; this readily affords what appears to be a 1 : 1′-dibromacetnaphthalide, but the greatest difficulty has been experienced in hydrolysing this compound.

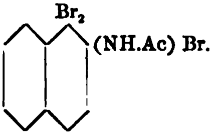
A second method consists in nitrating 1 : 4-bromonaphthalene sulphochloride. A 1 : 1′-nitrobromosulphochloride is readily obtained, but, although the chief product, it is by no means the only one.

A third and far simpler method consists in heating 1 : 4-bromonaphthalene sulphochloride with bromine and subsequently hydrolysing the 1 : 1-dibromosulphochloride, which is almost the exclusive product when the operation is properly carried out.

Although it is known that naphthalene-β-sulphonic acid is very readily converted into 1 : 4-dibromonaphthalene *hetero*-β-sulphonic acid, the order in which the bromine atoms enter has not been determined; and it is, in fact, difficult to arrest the action at an intermediate stage, the tendency to form the dibromo-derivative being very great. Mr. Stallard, however, having kindly placed a quantity of monobrominated β-sulphonate at the writer's disposal, it has been ascertained that it is an α_1-bromo-β_3'-derivative. By heating naphthalene-β-sulphochloride with a molecular proportion of bromine a very satisfactory amount of 1 : 3′-bromosulphochloride is readily obtained. The 'repellent' influence of an acid radicle is clearly brought out by these results, as β-bromonaphthalene yields 1 : 2′-dibromonaphthalene when brominated.

It is well known that there is often great difficulty, especially in the case of α-naphthol and α-naphthylamine, in obtaining satisfactory yields of bromo-derivatives, a considerable amount of by-product being formed, the nature of which has not been understood hitherto. Some light has been thrown on the nature of these products by observations made by Mr. Jenks and the writer.

Following the directions given by Cosiner and by Claus and Phillipson, monobrom β-acetnaphthalide was prepared by mixing bromine with β-acetnaphthalide dissolved in acetic acid; although the conditions were greatly varied, the amounts of pure product obtained were in all cases very unsatisfactory, rarely exceeding 25 per cent. The main product was a crystalline substance, more soluble in alcohol than monobromo-β-acetnaphthalide, but almost insoluble in acetic acid, ethylic acetate, chloroform, xylene and water. When digested with a weak solution of caustic soda this substance is converted into monobromo-β-acetnaphthalide, and the same effect is produced by digesting it with a solution of either sulphurous acid or potassium iodide. It appears to be probable that this substance contains the elements of a molecule of bromo-β-acetnaphthalide and a molecule of bromine; such a compound would contain 56·6 per cent. of bromine. The highest amount found was 52 per cent.; but as the substance undergoes decomposition when recrystallised from alcohol, it cannot be obtained pure. It is not produced by brominating bromo-β-acetnaphthalide, and therefore is probably formed together with it, being perhaps an addition compound, such as is represented by the formula



By digesting the crude product of the action of a single molecular proportion of bromine on one of β-acetnaphthalide with a weak solution of caustic soda, and then recrystallising from spirit, as much as 75 per cent. of the theoretical yield of bromo-β-acetnaphthalide can be obtained.

Rule expressive of the Formation of Sulphonic Acids.—Dressel and Kothe, in a recent most interesting paper,[1] have taken exception to the 'rule' suggested by Dr. Wynne and the writer, referred to in previous reports, that there is an 'invincible objection' on the part of two sulphonic groups to *remain* in either contiguous, or para-, or peri-positions; they have described a tri- and a tetra-sulphonic acid, each containing two sulphonic radicles in contiguous β β positions. We shall have occasion to discuss their results when the investigation of the changes attending sulphonation—the most difficult and complex chapter of the subject—is somewhat further advanced. It is only necessary to say that the 'rule' was merely an expression of the results up to that time obtained, and was never intended as a final statement.

The Investigation of the Cave at Elbolton.—Report of the Committee, consisting of Mr. R. H. TIDDEMAN (*Chairman*), Rev. EDWARD JONES (*Secretary*), Sir JOHN EVANS, Dr. J. G. GARSON, Mr. W. PENGELLY, *and* Mr. J. J. WILKINSON, *appointed to ascertain whether the Remains of Palæolithic Man occur in the Lower Cave Earth.*

THE work of excavation in this cave has now ceased. Since our last report the *débris* from the cave mouth has been cleared away, and in some material that was taken from the upper Neolithic layer a flint flake was found. Hitherto no flint tools had been discovered. A further depth of 10 feet was sunk to the bottom of the fissure, through a bed of sand and gravel, but no bones were found. The fissure still continues, being now only 5 to 6 feet in width. A total thickness of 60 feet has now been removed beneath the original cave floor. While an enormous quantity of bones have been obtained from the lower layer, yet no trace of Palæolithic man has been noticed, and, as this was the special purpose of the investigation, the Committee decided to bring the work to a close.

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[1] *Berichte*, 1894, 27, 1193–1210.

Fossil Phyllopoda of the Palæozoic Rocks.—Eleventh Report of the Committee, consisting of Professor T. WILTSHIRE (*Chairman*), Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*). (*Drawn up by* Professor T. RUPERT JONES.)

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1. *Elymocaris Hindei*, sp. nov.
2. Abdominal segments of a Phyllocarid from Moffat.
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5. Small *Estheria*, undescribed, from the Coal-measures.
6. *Estheria Dawsoni* from Nova Scotia.

1. A NEW species of Beecher's phyllocaridal genus *Elymocaris*, from the collection of Dr. G. J. Hinde, F.G.S., has been figured and described in the 'Geological Magazine' for July 1894, p. 292, pl. ix. fig. 7. It was found at Arkona, Ontario, Canada, in the Hamilton group of the Middle Devonian series.

Its nearest known ally is *Elymocaris capsella* (Hall and Clarke), from the Hamilton group of New York State, 'Palæont. New York,' vol. vii. 1888, p. 181, pl. xxxi. fig. 4. It differs, however, in details of outline, ornament, and ocular spot. The new species is named *E. Hindei*, after its discoverer.

2. Two imperfect sets of abdominal segments, impressed on a piece of Moffat Shale (from Garpel Linn), have been noticed in association with a carapace of *Discinocaris Browniana*, and therefore probably belonging to individuals of either that genus and species, or of *Aptychopsis*, or possibly *Peltocaris*, which also occur in the Moffat Shales. The two above-mentioned specimens are figured and described in the 'Geological Magazine' for July 1894, p. 291, pl. ix. figs. 4*a*, 4*b*. Fig. 3 shows the associated carapace. They belong to the Carlisle Museum.

We have noticed similar abdominal segments, but differing somewhat in size, associated with *Hymenocaris* in the Tremadoc slates, and with *Ceratiocaris* in the Upper Silurian beds. As such body-rings belong to various groups of these low-class Crustacea, it is not extraordinary that the above-mentioned genera should each possess the same kind of structure in the abdominal region.

3. A good-sized *Discinocaris Browniana* and the moiety of a rather large *Aptychopsis Wilsoni*, preserved in the Carlisle Museum, have also been described and figured in the July number of the 'Geological Magazine,' 1894, p. 292, pl. ix. figs. 5 and 6. They are typical of the Moffat Shales.

4. It may be remarked that the figured interior of the bipartite carapace of *Macrocaris Gorbyi*, Miller, referred to in our Tenth Report, at page 468, 'Report British Association' for 1893, appears (if looked at upside down) very much to resemble some of the bivalved *Aptychopses* figured in the 'Monograph of Palæozoic Phyllopoda,' Pal. Soc., 1892, pl. xv., but with a more acutely sagittate outline, and without the definitely concentric umbonal striæ.

If the carapace in the drawing (fig. 43) exposes its '*interior*,' it seems to lie unconformably with respect to the body-rings, for they appear to be covered by the carapace upside down. If it normally covered the body, it would show its *exterior*.

Is it possible that after death, the attachments of the body and carapace having been loosened, the carapace turned quite over, and the parts of the animal floated into a position reverse to what they held in life? Or have we here two valves and an imperfect body of an *Aptychopsis* which during decay were washed into a *reversed* position—that is, with the abdomen projecting from the anterior region, as is not unusual with some fossil *Ceratiocaridæ*?

5. By favour of Dr. Wheelton Hind, F.G.S., we have very lately seen, from Mr. George Wild's collection, some pyritous specimens of what seem to be a very small *Estheria* in shale from the roof of the Bullion Coal, Lower Coal-measures, lately worked at Trawden, near Colne, in North-east Lancashire.

6. A specimen of *Estheria Dawsoni*, Jones ('Geol. Mag.,' 1870, p. 220, pl. ix. fig. 15; *ibid.*, 1876, p. 576; *ibid.*, 1878, p. 101, pl. iii. fig. 2), has been obtained from the vicinity of Five-Islands, Nova Scotia, by Mr. H. Fletcher, of the Geological Survey of Canada. Like a former specimen, it may be from the Horton Series; and has been sent by Sir W. Dawson, F.R.S., of Montreal, for our examination.

Exploration of the Calf Hole Cave at the Heights, Skyrethorns, near Skipton.—Report of the Committee, consisting of Mr. R. H. TIDDEMAN (*Chairman*), Rev. E. JONES (*Secretary*), Professor W. BOYD DAWKINS, Professor L. C. MIALL, Mr. P. F. KENDALL, Mr. A. BIRTWHISTLE, *and* Mr. J. J. WILKINSON.

THIS cave lies on the west side of a limestone scar on the Heights Farm, and its entrance is about 30 feet above the plain at the foot of the scar. The entrance chamber is 33 feet long and from 14 feet to 26 feet in width. A well-buttressed column of rock supports the roof, forming two archway entrances to the cave. The outlook westward from these entrances is very fine, and the platform would be of value to prehistoric man as a shelter. At the north-east corner of the entrance chamber is another cave, here 8 feet wide, and which after a short course of 10 feet turns eastward. This latter cave was originally blocked up, and a former tenant of the farm attempted to open it out. He found a few worked flints, a long iron spear-head, and the bones of numerous small mammals. But the ignorance and want of skill of the workers made their finds of little value. In August of 1893 your Secretary made some experimental trenches in the entrance chamber. In one cutting on the east side of the pillar, at a depth of 18 inches, a remarkable and unique implement was found resting on a bed of clay. The tool consists of a haft 6 inches long of reindeer antler with a socket at the upper end. A well-rounded hole half an inch in diameter has been made through the haft. The circumference of the haft is 4½ inches at the socket and 5¾ inches at the other end. Into the socket has been well inserted a large tooth, forming a powerful chisel, which would be of great value to its possessor. The hole in the middle of the haft might be for the insertion of a thong to be fastened round the waist. The character of the tooth, whether boar or hippopotamus, has not yet been ascertained. Another trench was cut towards the little cave, and here, near the surface, were found a neat flint saw and a flint flake.

Since the last meeting of the Association, and with the aid of the small grant given to us, much preliminary work has been done to render possible a thorough and orderly exploration. The material that had been taken out of the little cave by the previous explorers and placed in the entrance chamber was first cleared away. Thin 'spits' of about 6-inch layers were taken successively from the surface of the entrance chamber, carefully examined, and then tipped outside the cave. The top layer of 2 or 3 inches was of loamy clay, crowded with bones of small animals, frogs, rats, voles, &c. Beneath this was a layer, varying from a foot to 18 inches thick, of darkened earth containing angular fragments of limestone, some burnt sandstones, bones of sheep, horse, fox, badger, rabbit, hare and otter, bits of charcoal and charred bird-bones. In this layer a few flints were found, and at the bottom, resting on the clay, was the hafted tool. This implement is thus most likely of Neolithic age, though it was found on the top of the more ancient layer which contained the bones of bison, &c.

The lower layers consist so far of irregular beds of washed-in stuff, stiff clay, then sandy clay over patches of gravel and sand. In this material are rounded boulders of both grit and limestone, together with pieces of stalagmite. On none of the boulders have we noticed any ice-scratches. Fragments of bones are interspersed throughout the mass, sometimes embedded in the patches of stiff clay as well as in the gravel and sands. These bones are of very different character from those found in the upper layers. They are mostly dark in colour, much mineralised, and thus heavy. The bones so far identified belong to the bison, reindeer, roebuck, horse, and grizzly bear. Some show evidence of having been gnawed. Most of them are very fragmentary, often only sharp splinters. From the current bedding it seems that the bones must have been washed into the cave by the same means as the grits and limestone boulders. The finds are not abundant; yet from the variety obtained the excavation promises to be interesting in confirming the lists of Pleistocene fauna that have been found in other parts of North-east Yorkshire.

The Committee are indebted to Sir Matthew Wilson for permission to explore on his estate, and for his kindly co-operation in their work.

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest in the United Kingdom.—Fifth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Dr. VALENTINE BALL, Mr. JAMES E. BEDFORD, Professor W. BOYD DAWKINS, Mr. EDMUND J. GARWOOD, Mr. J. G. GOODCHILD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. ARTHUR S. REID, Mr. J. J. H. TEALL, Mr. R. H. TIDDEMAN, Mr. W. W. WATTS, Mr. HORACE B. WOODWARD, *and* Mr. OSMUND W. JEFFS (*Secretary*). (*Drawn up by the Secretary.*)

SINCE the last Report, presented at the Nottingham meeting of the Association, your Committee have been enabled to add 215 photographs to their collection, which has now reached a total of 1,055. This number, again, shows a gratifying increase as compared with the two previous years. The majority of these were, however, received late in the year, and it has been found impossible to have them all arranged for exhibition before the date of the opening meeting at Oxford. Your Committee, therefore, respectfully suggest reappointment for another year at least, in order to enable a complete and revised catalogue to be drawn up, which would be more valuable for reference than the partial lists appearing in the various annual reports. During the next year it is hoped that societies who have been for some time engaged in the work of systematic photography of geological sections in their districts, but have not yet sent in the results obtained, will be able to make further progress with the work and enable the Committee to make their own collection more complete. The collection has now assumed such proportions that a rearrangement of a more systematic character than has hitherto been possible has become necessary, and with the additions that are expected from various sources this rearrangement in suitable albums and cases, duly indexed, will occupy some time.

The question of the location of the large number of photographs now obtained has received the serious attention of the Committee, and they have recommended to the Council that the collection be deposited at the Museum of Practical Geology, London, where, in their opinion, it would be most accessible to the general public for purposes of reference.

At a meeting of the Committee held during the Nottingham meeting several matters were discussed bearing upon the furtherance of the objects for which the Committee were appointed. The various local societies have been again urged, by circular, to assist the scheme of the Committee with the object of completing a national collection of photographs, to serve as a photographic survey of the geology of our own country.

The Committee, having invited the views of members who are practical photographers as to the most suitable form of camera for geological field work, beg to tender their thanks to Drs. Tempest Anderson and H. J. Johnston-Lavis, and to Messrs. Wilbert Goodchild, A. R. Hunt, C. Defieux, and F. N. Eaton for suggestions and assistance rendered. It still appears to be difficult to recommend a particular form of instrument, as almost every photographer has his own favourite camera, and the apparatus required varies with the class of work to be undertaken in the field. It is proposed, however, to give in the next Report some hints which may be of use to those engaged in photographing rocks and other geological features.

Among the donations of photographs added to the collection during the past year are several of great scientific value as illustrations of geological interest. The Committee desire to record their obligations to the following donors of photographs :—The Belfast Naturalists' Field Club, Croydon Natural History and Microscopical Society, Leicester Literary and Philosophical Society, the Manchester Geographical Society, and the Perthshire Society of Natural Science ; Miss Mary K. Andrews, Dr. Valentine Ball, Messrs. F. J. Allen, W. H. Alexander, Montagu Browne, R. G. Brook, Henry Coates, F. N. Eaton, H. D. Gower, Wm. Gray, Wilbert Goodchild, E. J. Garwood, W. Lamont Howie, H. L. P. Lowe, J. G. McDakin, G. A. Piquet, H. Preston, C. J. Watson, and R. Welch. The Belfast Naturalists' Field Club have contributed an exceedingly valuable series of photographs illustrating the Antrim chalks and basalts, together with some fine examples of marine denudation. The extensive series of whole-plate prints, taken by Messrs. J. Burton and Sons for the Leicester Literary and Philosophical Society (for which the Committee are indebted to the good offices of Mr. Montagu Browne), afford some characteristic examples of the advantageous application of photography to geological illustration.

The following suggestions have been received as to suitable sections, &c., of which photographs are desirable, and the Committee hope that some photographer in the localities mentioned will be able to undertake the work :—

Mr. H. C. Beasley (*Hon. Sec. Liverpool Geological Society*).

Section in quarry (50 feet) between Rednall and Kendall End, Lickey Hills, showing fault with contortions in the Lickey quartzite.

Dr. C. Callaway, *F.G.S.* (*Wellington, Salop*).

Section of Uriconian tuffs and conglomerates in large quarry at Lawrence Hill at the foot of the Wrekin, two miles from the railway station, Wellington, Shropshire.

Section of Longmyndian conglomerate by the side of the road at Bagston Hill, two miles south of Shrewsbury.

Section of May Hill Sandstone resting unconformably upon Lower Ordovician rocks at Hope, two miles from Minsterley Station, Shropshire.

Section of contorted Ordovician strata at Hope, near Minsterley.

Sections of Wenlock limestone around Much Wenlock, Shropshire.

Section of passage beds between Wenlock limestone and Wenlock shale, on the road from Wenlock down to Harley, about one mile from Wenlock.

Section of basal Carboniferous beds resting on Wenlock shale in road called Jigger's Bank, about a mile from Coalbrookdale Station, Shropshire.

Sections of waterstones (Lower Keuper), with perhaps slabs of footprints of *Rhynchosaurus*, at Grinshill, near Yarton Station, Shropshire.

Sections of glacial sands at Ketley, one mile from Wellington, Shropshire.

IRELAND.

Near Londonderry. West of the 'B of 'Burnfoot' on the one-inch Ordnance map. Quarry. Grit and black schist contorted.

Near Buncrana. On shore near Ned's Point. Examples of contortion and overthrust.

Between Buncrana and Fahan, near Fahan. On the shore. Fine examples of crushing and contortion.

Galway town. East of town, on shore. Gneisses seen in crag sections. Very curious, made by fragments of hornblende rock in granite.

Lisoughter, Western Galway. Ophicalcite quarries.

Glendalough, ditto. South of the hotel. Crags showing granite running along joints of diorite.

Mr. J. W. WOODALL, F.G.S. (St. Nicholas House, Scarborough), suggests the desirability of having photographs taken of the series of sections on the Yorkshire coast from Redcar to Flamborough Head, and will be glad to give assistance to photographers.

The following table shows the number of photographs registered since the issue of the Report for 1893 :—

ENGLAND AND WALES:		
Cumberland	5	
Denbighshire	3	
Derbyshire	3	
Gloucestershire	1	
Kent	3	
Lancashire	2	
Leicestershire	31	
Merionethshire	1	
Monmouthshire	1	
Norfolk	2	
Northumberland	11	
Surrey	2	
Somerset	10	
Warwickshire	6	
Westmoreland	5	
Yorkshire	3	
	—	89
SCOTLAND:		
Edinburgh	32	
Perth	10	
	—	42
CHANNEL ISLANDS		1
IRELAND:		
Antrim	39	
Down	25	
Galway	1	
Fermanagh	1	
Dublin	12	
Donegal	5	
	—	83
Total		215

GENERAL SUMMARY.

England and Wales	685
Scotland	125
Ireland	206
Channel Islands	4
Isle of Man	23
Microscopical sections	12
Total	1,055

FIFTH LIST OF GEOLOGICAL PHOTOGRAPHS.

(TO AUGUST 1894.)

NOTE.—This list contains the subjects of geological photographs, copies of which have been received by the Secretary of the Committee since the publication of the last Report. Photographers are asked to affix to their negatives the registered numbers, as given below, for convenience of future reference.

Copies of photographs desired, and, in many cases, lantern slides, can usually be obtained either from the photographer direct or from the officers of the local society under whose auspices the views were taken.

The price at which prints or lantern slides may be obtained depends upon local circumstances, over which the Committee have no control.

The Committee find it necessary to reiterate the fact that they do not assume the copyright of any photographs included in this list. Inquiries respecting them, and applications for permission to reproduce photographs, should *not* be addressed to the Committee, but to the photographer direct.

[*Enlargements are marked* (*E.*)]

ENGLAND AND WALES.

CUMBERLAND.

Photographed by WILBERT GOODCHILD, 2 *Dalhousie Terrace, Edinburgh.*
Size 6 × 4 *inches.*

Regd. No.		
1046	Crossfell	Scenery of Carboniferous rocks
1048	„ Eden Valley .	Blocks of Millstone grit

DENBIGHSHIRE.

Photographed by R. G. BROOK, *St. Helens.* *Size* 8 × 6 *inches.*

887–888	Llandulas, near Abergele .	Panorama of limestone quarries
889	Pistill Rhaiadr . . .	Waterfall

DERBYSHIRE.

Photographed by HARRY SOWERBUTTS, *Manchester Geographical Society.*
(*Per* ELI SOWERBUTTS, *F.R.G.S.*) *Size* 6 × 4 *inches.*

880	Miller's Dale . . .	Carboniferous limestone
881–882	„ . . .	„ „ and toadstone

GLOUCESTERSHIRE.

Photographed by H. L. P. LOWE, *Shirenewton Hall, Chepstow.*
Size 6 × 4 *inches.*

879	Chepstow	Anticlinal in Carboniferous limestone

KENT.

Photographed by Captain J. G. McDAKIN, 15 *Esplanade, Dover.*
Size 8½ × 6½ *inches* (*E.*)

866	Dover Cliffs . . .	Fall of cliff (Middle and Upper Chalk)
867	„ . . .	Landslip at 'The Warren'
868–869	Sandgate	House fissured by landslip

LEICESTERSHIRE.

Photographed by J. BURTON & SONS, *Leicester, for the Leicester Literary and Philosophical Society.* (*Per* MONTAGU BROWNE, *F.Z.S.*) *Size* 12 × 10 *inches. Lantern slides can be obtained.*

Regd. No.		
927	Humberstone	Erratic block of syenite (21 tons)
931	Aylestone	,, ,, Mount Sorrel granite (10 tons)
928	,,	Boulder clay on middle glacial sand
929	,,	,, ,, Keuper marls
930	,, Saffron Lane	Small erratic blocks in boulder clay
932–933	Barrow-on-Soar	Lower Lias limestone, showing contortions
934–936	Woodhouse Eaves, 'Hanging Stone' rocks	'Charnwood slates'
937	Broombriggs, Charnwood Forest	,, ,,
938	Woodhouse Eaves	Cavern in 'Charnwood slates'
939–940	Breakback Hill	Slates dipping 45° S.E.
941	,,	Upper Keuper lying unconformably on slates
942	Swithland	,, ,, on slate
943–944	Benscliff	'Charnwood slates'
945–946	Woodhouse Eaves, Ring Pit Quarry	Slates, showing concentric rings
947	Stony Stanton	Southerly exposure of Charnwood Forest rocks
948–949	Mount Sorrel	Terraces of hornblendic granite
950–957	Croft Hill	Triassic shore-line with rolled blocks of greenstone, covered by Upper Keuper marls

MERIONETH.

Photographed by C. J. WATSON, *Acock's Green, Birmingham.*
Size 6 × 4 *inches.*

850	Barmouth	Glacial groovings on Cambrian strata

MONMOUTH.

Photographed by H. L. P. LOWE, *Shirenewton Hall, Chepstow.*
Size 6 × 4 *inches.*

878	Crich Road, Shirenewton	Jointing and weathering of rocks

NORFOLK.

Photographed by H. PRESTON. (*Per* H. W. WOODWARD, *F.G.S.*)
Size 4 × 3 *inches.*

883	Sherringham	Contorted glacial drift
884	Thorpe Crag, near Norwich	Norwich Crag on Chalk

NORTHUMBERLAND.

Photographed by E. J. GARWOOD, *Newcastle-on-Tyne.*
Size 12 × 10 *inches* (*E.*)

888–889	Howick Bay	'Trough fault'
890	Cullenose	Felspathic grit and shale
891	,,	'Fern fathom' limestone

Regd. No.		
892	Howick	False-bedded sandstones
893	„	Intrusion of 'whin' in limestone
894–895	„	Faults in limestone
896	Dunstanborough . .	Columnar 'whin sill'
897	Bamburgh, Harkes Rocks .	'Whin' traversing Carboniferous rocks
898	Cuddy's Cove, Cockenheugh	Pillar rock
899–900	„ „ „ .	Enlarged view, showing weathering
901	Craster	'Whin' overlapping felspathic grit

SOMERSET.

Photographed by F. J. ALLEN, *Mason College, Birmingham.*
Size 8 × 6 *inches.*

852–857	Burrington, Mendip Hills .	Denudation of Carboniferous limestone
858	Cheddar Pass . . .	„ „ „
862	Dinder Wood, Mendip Hills	Rock shelter
865	Croscombe Hills . .	Dolomitic conglomerate

Size 6 × 4 *inches.*

859, 861	Cheddar Pass . . .	Erosion of Carboniferous limestone
860	Lion Rock, Cheddar . .	„ „ „
863–864	Dinder Wood . . .	„ „ „

SURREY.

Photographed by HARRY D. GOWER, 16 *Wandle Road, Croydon.* (*Per Croydon Microscopical and Natural History Society.*) *Size* 6 × 4 *inches.*

885	Tilburstow Hill . . .	Escarpment in Lower Greensand
886	Godstone, silver sand pits .	Lower beds of the Upper Greensand

WARWICKSHIRE.

Photographed by C. J. WATSON, *Acock's Green, Birmingham.*
Size 6 × 4 *inches.*

844–846	Nuneaton	Triassic marl resting unconformably on Cambrian quartzite, with intrusive diorite beneath
847, 848	„	Cambrian quartzite
849	Purley Park . . .	Diorite (rudely columnar)

WESTMORELAND.

Photographed by WILBERT GOODCHILD, 2 *Dalhousie Terrace, Edinburgh.*
Size 6 × 4 *inches.*

1039	Head of Haikable, or Highcupgill, Appleby	'Whin' in Carboniferous rocks
1040, 1047	Udale, Milburn . .	Waterfall in Carboniferous limestone
1041	„ below Middletongue	Rock-strewn river bed
1042–1044	Orton	Weathered joints ('grikes') in Carboniferous limestone
1045	Dufton, from Bakstone Edge	Great Pennine fault
1049	Silveraband, Milburn .	'Swallow holes' in Carboniferous limestone

YORKSHIRE.

Photographed by W. H. ALEXANDER, 14*a Chorley Old Road, Bolton.*
Size 4 × 3 *inches.*

Regd. No.		
874-876	Sawley (Chasburn)	Synclinal and anticlinal foldings in limestone and shale

Photographed by F. N. EATON, *Roseville, Maghull, Lancashire.*
Size 4 × 3 *inches. Lantern slides can be obtained.*

841	Ingleton	Craven fault
842, 843	„	Fall on River Greta

CHANNEL ISLANDS.

Photographed by GEO. A. PIQUET, 63 *New St. John's Road, Jersey.*
Size 8 × 6 *inches.*

851	St. Owen's, Jersey	Semi-detached pillar of granite (vein of greenstone at base)

SCOTLAND.

EDINBURGH.

Photographed by WILBERT GOODCHILD, *Dalhousie Terrace, Edinburgh.*
Size 6 × 4 *inches.*

1012-1014	Canonmills, Edinburgh	False bedding in Pleistocene sands
1015-1017	Salisbury Craigs	Junction of dolerite of Lower Carboniferous sandstone
1018	Arthur's Seat	Columnar basalt
1019, 1032	Glencorse reservoir	Stream cutting through tuffs of Middle Old Red Age
1020	Braid Burn	Cutting through the massif of Middle Old Red Age
1021	Arthur's Seat	View from Driddingston Loch
1022	„ 'Haggis Knowl'	Basalt lava
1023	Arthur's Seat, St. Anthony's Chapel	„
1024, 1025	Arthur's Seat (Panoramic view)	Lower Carboniferous basalt
1026	Blackford Hill, Old quarry	Weathered lava
1027, 1028	Hailes Quarry, near Edinburgh	Laminated Lower Carboniferous sandstones
1029	Arthur's Seat, from Cameron Bridge	Alluvial flat of Duddingston Loch
1033	Craiglockhart, Edinburgh	Great fault in railway cutting. (Upper Old Red and Granton sandstone)
1034, 1035	Craiglockhart, Edinburgh	Smaller faults in railway cutting
1036	Arthur's Seat, from brick field, Portobello	Volcanic neck
1037	Braid Hills, from Blackford Hill	Middle Old Red volcanic rocks
1050, 1051	'The Kipp,' from Kitchen Moss, Pentland Hills	„
1052	Salisbury Craigs	View from St. Leonard's

Regd. No.		
1053	Logan Burn, Pentland Hills	Middle Old Red conglomerate
1054, 1055	Arthur's Seat, from Salisbury Craigs	Lower Carboniferous sandstones overlying dolerite

HADDINGTONSHIRE.

Photographed by WILBERT GOODCHILD, *Dalhousie Terrace, Edinburgh. Size* 6 × 4 *inches.*

1030	North Berwick . . .	Marine erosion in Lower Carboniferous tuffs
1031	" " Craighleith in distance	Marine erosion
1038	Canty Bay . . .	Marine 'pot-holes'

PERTH.

Photographed by W. ELLISON, 2 *Dalhousie Street, Perth.* (*Per* HENRY COATES, *F.R.S.E., Perthshire Society of Natural Science.*) *Size* 8 × 6 *inches.*

870	Glen Turret . . .	Glacial barrier across valley
871–872	Glenartney . . .	Waterfall, basaltic dyke crossing stream
873	" . . .	Disintegration of basaltic dyke

IRELAND.

Co. ANTRIM.

Photographed by Miss M. K. ANDREWS, *College Gardens, Belfast.* (*Per Belfast Naturalists' Field Club.*) *Size* 4 × 3 *inches.*

993–995	Greenisland, Carrickfergus	Boulder clay, with erratics
996–997	Carnmoney . . .	Boulder clay, overlying basalt and chalk
902–906	Kenbaan . . .	Chalk and basalt
907–911	Giant's Causeway . .	Columnar basalt

Photographed by WM. GRAY, M.R.I.A., *Mount Charles, Belfast.* (*Per Belfast Naturalists' Field Club.*) *Size* 12 × 10 *inches* (*E.*).

987	Larne	Raised beach of gravel on estuarine clay
988	Whitehead . . .	Boulder clay on New Red sandstone
989	Fair Head . . .	Denudation of basalt
990	Soldierstown. . .	Flint nodules
991–992	White Rocks, Portrush .	Denudation of chalk

Photographed by R. WELCH, 49 *Lonsdale Road, Belfast.* (*Per Belfast Naturalists' Field Club.*) *Size* 8 × 6 *inches.*

[NOTE.—Lantern slides of the following subjects can be obtained. For complete list see Mr. Welch's Geological Catalogues.]

963	Glengariff Glen . .	Large 'pot-hole'
964	Cushenden . . .	'The Great Cave'
965	Peat Bog, Armoy . .	Showing roots of trees
966	Glenarm . . .	Inclined Chalk beds
967	Cave Hill, Belfast . .	Escarpment
968	Glendun . . .	General view of glen
969–971	Whitewell . . .	Basalt or eroded surface of Chalk

Regd. No.		
972–974	Cave Hill, Belfast.	Trap overlying old cliffs and talus of Chalk
975	Red Bay	New Red conglomerate
976	Maylena	Current bedding in drift sands
977	Glenarm	Natural arch in Chalk
979	Portrush	„ „
978	Glenariff	General view of valley
980	Cushendall	Tertiary volcanic neck in Old Red sandstone
981	Murlough Bay	General view
982	Fair Head, Ballycastle	Marine erosion of Lower Carboniferous sandstone. Dolerite in distant cliff

Co. DONEGAL.

Photographed by R. WELCH, *Belfast.* (*Per Belfast Naturalists' Field Club.*) *Size* 8 × 6 *inches.*

959	Port Salon	Marine erosion of quartzite
962	„	Natural arch
960	Muckross Head	Marine erosion
961	Port Leuca	„ „

Co. DOWN.

Photographed by R. WELCH, *Belfast.* (*Per Belfast Naturalists' Field Club.*) *Size* 8 × 6 *inches.*

983	Grey Abbey	Erratic block (basalt, 500 tons)
984	Newcastle	Sand dunes and raised beach
985	Edenderry	'Esker drift'
986	Happy Valley, Mourne Mountains	General view

Photographed by WM. GRAY, M.R.I.A., *Mount Charles, Belfast. Size* 12 × 10 *inches* (*E.*)

983A	Cloughmore	Block of Mourne granite
984A	The Butterlump, Strangford	Erratic block (basalt) resting on New Red sandstone
985A	On the shore, Lough, near Bloody Bridge	Silurian rocks
986A	Ballyquinten Point	Vertical beds, Silurian rocks

Photographed by Miss M. K. ANDREWS, *College Gardens, Belfast. Size* 4 × 3 *inches.*

912–913	Bloody Bridge	Granite boulder
914	Belmont	Spheroidal basalt
998–1000	Newcastle, Glen River	Junction of granite and Silurian rocks
1001–1003	Kilcoo	Moraine, cut through by river
1004–1006	Dundonald, Ballyoran	Boulder clay on Trias
1007–1008	Dundonald, Ballyoran, Cairowreagh quarry	Boulder clay
1009–1011	Neilby Hill	Current bedded drift sand

Co. DUBLIN.

Photographed by Dr. VALENTINE BALL, *C.B.*, *F.R.S.*, *Dublin. Size* 8 × 6 *inches.*

916–919	Howth	Cambrian boulder-bed
920, 921	Stake Rock	Cambrian quartzite, with drift on ice-planed surface

Regd. No.		
922	Howth	Cambrian quartzite (showing bedding)
923, 924	Sutton Shore, Howth	Glacial drift
925	„ „	Drift on ice-truncated edges of Cambrian slates
926	„ „	Carboniferous limestone partly altered into dolomite

Co. Fermanagh.

Photographed by R. Welch, 49 *Lonsdale Street, Belfast.*
Size 8 × 6 *inches.*

958	Enniskillen	The 'Marble Arch'

Co. Galway.

Photographed by H. L. P. Lowe, *Shirenewton Hall, Chepstow.*
Size 6 × 4 *inches.*

877	Pass of Salruch, Little Killery River, Connemara	Erosion of river valley

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The Circulation of Underground Waters.—Twentieth Report of the Committee, consisting of Dr. E. Hull (*Chairman*), Sir Douglas Galton, Messrs. J. Glaisher, Percy Kendall, Professor G. A. Lebour, Messrs. E. B. Marten, G. H. Morton, Professor Prestwich, Messrs. I. Roberts, Thos. S. Stooke, G. J. Symons, W. Topley, C. Tylden-Wright, E. Wethered, W. Whitaker, *and* C. E. de Rance (*Secretary*). (*Drawn up by* C. E. de Rance.)

The reporter has made good progress with the digest of the previous nineteen reports, which will be ready for publication this year, giving the details grouped in geological formations and counties.

The reporter, through unavoidable circumstances, is unable to be present this year, and is anxious to point out that not only has the Cardiff Naturalists' Society sent a valuable contribution, but several other societies federated to the British Association intend to furnish information; this being the case, he ventures to point out that it appears desirable to continue the work of your Committee, and that it is evident that if the work entrusted to them in 1874 be terminated in 1894 it will be continued by the federated societies, but the details of sections and analyses will be scattered over many publications and will not be of general use and access to engineers and sanitarians, and the results obtained will be published under various modes and conditions not admitting of common reference, as is the case in the reports emanating from your Committee.

The Committee would therefore venture to suggest that, as valuable information can still be obtained through the agency of local societies, they be reappointed without grant.

Your Committee have to deplore the death of one of their original members, Mr. Wm. Pengelly, F.R.S., who contributed most valuable information in the early days of the investigation, and throughout has taken an active interest in the work.

South Wales.

Section of Well-boring at Messrs. J. Edwards & Co.'s, Aerated Water Manufacturers, Llandrindod Wells.

Information collected by the Cardiff Naturalists' Society per Mr. F. T. Howard, chiefly from Messrs. Isler and Co., London.

—	Feet	Inches	Feet	Inches
Old well	6	6	—	—
Clay and stone	1	—	7	6
Stone	4	—	11	6
Clay and stone	26	6	38	—
Yellow clay	6	—	44	—
Stone	4	—	48	—
Clay and stone	19	6	67	6
Clay	6	—	73	6
Loam	15	6	89	—
Shale	5	—	94	—
Rock	42	6	136	6

Lined to 95 feet with 3-inch internal diameter tube, the top of which stands 2 feet below surface. Supply, 360 gallons per hour. Water not of satisfactory nature; the boring is to be continued. Water first touched at about 90 feet from surface.

Section of Well at S. B. Sketch's, Esq., Pembroke Dock.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Marl and stone	3	—	—	—
Red rock	10	—	13	—
Sand	1	6	14	6
Red rock	4	—	18	6
Sand	1	6	20	—
Red rock	10	—	30	—
Stone	1	—	31	—
Red rock	4	9	35	9
Rock	—	6	36	3
Red rock	6	3	42	6
Rock	7	—	49	6
Stone	1	6	51	—
Rock	6	6	57	6
Red rock	4	—	61	6
Red rock	1	6	63	—
Red rock	37	—	100	—
Red rock	12	6	112	6
Red rock	7	6	120	—

Lined with 5-inch tube to 30 feet. Supply, 3 gallons per minute. Water level, 8 feet from surface. Water first touched at about 10 feet.

Section of Well at E. T. Lydden's, Esq., Llanishen, near Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Pit through clay and stones	5	—	—	—
Clay and stones	5	—	10	—
Ballast	6	—	16	—
Running sand	2	—	18	—
Ballast	5	—	23	—
Red gravel	5	—	28	—
Sand	1	—	29	—
Red gravel (Upper Old Red Sandstone)	5	—	34	—
Red marl	6	—	40	—
Red rock	9	—	49	—
Conglomerate rock	1	—	50	—
Red rock	2	—	52	—
Conglomerate rock	2	—	54	—
Red rock	11	6	65	6
Stiff red marl	1	6	67	—

Lined to 40 feet with 4-inch tube from surface. Water level, 23 feet from surface. Supply pumped down in five minutes with 4-inch pump, but rises again directly. Water first touched at 47 feet from surface.

Section of Well, Ely Brewery Company, Limited, Ely, near Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well	7	—	—	—
Ballast and sand	17	—	23	—
Marl and cobbles	10	—	33	—
Marl and radyr stone	8	—	41	—
Radyr stone	34	—	75	—
Red marl	54	—	129	—
Rock	3	—	132	—
Stone	1	6	133	6
Rock	13	2	146	8
Marl	2	6	149	2
Rock	4	2	153	4
Radyr stone	25	—	178	4
Limestone	1	3	179	7
Radyr stone	13	11	193	6

25 ft. 8½-in. tube, 4 ft. 6 in. below surface.
125 ft. 7¼-in. tube, 4 ft. below surface.

Supply, 72 gallons in 74 seconds. Level of water, 7 feet from surface. Water first touched in rock about 125 feet from surface.

Section of Well at Messrs. H. Anthony & Co.'s, Castle Brewery, Great Frederick Street, Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well (Alluvial deposits)	5	—	—	—
Marl	2	—	7	—
Clay with boulders of Millstone Grit	3	—	10	—
Clay and pebbles (Alluvium)	10	—	20	—
Red marl	23	—	43	—
Rock	2	3	45	3
Red marl	17	9	63	—
Rock	3	6	66	6
Red marl	53	6	120	—

Lined with 45 feet of 8½-inch internal diameter tubes, tops of which stand 8 feet 6 inches below surface, and 115 feet of 7¼-inch internal diameter tubes, tops of which stand 3 feet 6 inches below surface. Water level, 21 feet below surface. Supply, over 1,080 gallons per hour. Water first touched at 23 feet from surface, when the level was 16 feet from surface. This well is important as indicating a third possible horizon from which water may be obtained. The usual horizon is the junction of the dolomitic conglomerate and the red marls. This bed is approximately 200 feet higher in the series. The water was hard, containing Mg and Ca sulphates and carbonates, also NaCl.

Section of Well at Messrs. Bird & Son's, East Moors, Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well	22	—	—	—
Pebbles (alluvium)	12	—	34	—
Loamy marl	10	—	44	—
Marl	57	—	101	—
Blue marl	7	—	108	—
Marl	113	—	221	—
Marl and gypsum	7	—	228	—
Marl	118	—	346	—
Rock	3	—	349	—
Red marl	4	6	353	6

Lined with 25 feet of 11½-inch tube, top of which stands 22 feet below surface, and 100 feet of 10-inch tube, top of which stands 21 feet below surface. Water level, 20 feet below surface. Supply good. Water first touched at about 150 feet from surface.

Section of Well at Messrs. Brain & Co.'s Old Brewery, Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Pit	10	—	—	—
Gravel[1]	15	6	25	6
Red marl	253	6	279	—
Rock	1	—	280	—
Red marl	21	6	301	6
Grey rock	19	9	321	3
Red marl	10	3	331	6

Lined with 30 feet of 8½-inch tube, top of which stands 9 feet 9 inches below surface, then with 166 feet of 7½-inch tube, top 9 feet 6 inches below surface. Water level, 26 feet 6 inches below surface. Supply, 2,600 gallons per hour. Supply tapped at about 322 feet from surface.

Section of Well at Messrs. Owen & Co.'s, Limited, Ely Paper Mills, Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Pit	6	—	—	—
Made ground	10	—	—	—
Sandstone	8	—	18	—
Gravel	10	—	28	—
Rock	8	—	36	—
Red marl	14	—	50	—
Rock	41	—	91	—
Red rock	4	—	95	—
Hard red marl, with layers of rock	7	—	102	—
Hard rock	2	2	104	2
Hard red marl	14	10	119	—
Hard red marl, with layers of rock	6	—	125	—
Rock	1	—	126	—
Red and green marl	—	6	126	6
Hard red marl	6	—	132	6
Hard red and green marl	4	—	136	6
Grey rock	8	—	144	6
Red and green marl and rock	2	—	146	6
Rock	1	6	148	—
Grey rock	7	—	155	—
Rock	39	2	194	2
Grey rock	3	10	198	—
Hard rock	20	—	218	—
Blue rock	4	6	222	6
Hard rock	21	6	244	—

Supply, 12,000 gallons per hour. Water level, 11 feet from surface. Supply first tapped at about 157 feet from surface. Lined with 25 feet of 13-inch tubes, from 4 feet 6 inches from the surface.

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[1] Alluvial

Messrs. W. Hancock & Co.'s, Limited, Phœnix Brewery, Cardiff.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well	20	—	—	—
Marl	38	—	58	—
Rock	2	6	60	6
Marl and rock	65	6	126	—
Marl	109	—	235	—
Marl and rock	7	6	242	6
Marl	20	6	263	—
Rock	2	6	265	6
Marl	20	6	286	—
Rock	1	9	287	9
Red rock	2	6	290	3
Rock	20	3	310	6 [1]
Red rock	20	—	330	6
Rock	5	3	335	9

Sand with grains of 'gold' [? sulphuret of iron] and hæmatite. Boring in progress.

Section of Well at Rhymney Railway, Cardiff.

—	Feet	Inches	Feet	Inches
Dug well	62	—	—	—
Red marl	88	—	150	—
Rock	27	—	177	—
Conglomerate	13	—	190	—
Red marl	9	—	199	—
Rock	137	—	336	—

Lined with 30 feet of 8½-inch tube, 53 feet below surface. 120 feet of 7¼-inch tube, 51 feet below surface. N.B. 100 feet of 7¼-inch tubes are perforated. Water level, 39 feet from surface. Supply good. Water tapped at about 130 feet from surface.

[1] Small crystals of selenite.

Well sunk at South Wales Portland Cement and Lime Works, Lim., Penarth, near Cardiff, in 1892.

Collected by the Cardiff Naturalists' Society.

Ground Level	Feet	Inches	Remarks
Bottom of the Lias . . .	10	0	—
Laminated black bituminous shale	—	6	—
Blue clay	—	4	—
Paper shale	—	14	—
Hard bluish stony magnesian marl	6	6	Much pyrites.
Stone	—	3	—
Marl	2	0	—
Stone	1	0	—
Marl	—	8	—
Stone	—	2	—
Stone	—	1	—
Stony marl	1	3	—
Stone	—	3	—
Stony marl	3	0	—
Stone	—	$2\frac{1}{2}$	—
Shale	—	11	—
Stone	—	1	—
Shale	3	10	—
Stone	—	1	—
Marl	—	23	—
Stone	—	6	Strong sulphurous spring. Much iron pyrites in bed.
Hard shale	6	8	—
Stone	—	2	—
Stone	—	2	—
Shale	—	8	—
Stone	—	2	—
Marly shale	3	10	—
Light stone	—	6	—
	—	8	—
Dark stone	—	11	'Marl stones;' no water or fossils.
	3	0	
Light stone	—	11	—
Dark stone			
Very hard dark blue and light green stones	About 15	0	No water.
Lightish and white marl . .	„ 10	0	—
Hard red marl	—	—	Much water; thin band only 10 ft.; about 2,000 gallons per hour.
Whitish hard marls . . .	13	0	—
Stony matter, greenish marls, gypsum, and hard red marls in thin bands	7	9	—
Red marl for about 120 ft. Gypsum band at base	—	—	Very much water from gypsum bands.

The water level varies within a range of 25 feet. Not connected with the tides, but a regular ebb and flow within limits of 4 or 5 feet. Analysis shows the water to be highly charged with $CaSO_4$, almost to saturation; also much $CaCO_3$. Smaller quantity of $MgSO_4$, NaCl, $MgCl_2$.

Information from the manager (W. J. Cooper, Esq.) through Cardiff Naturalists' Society.

NORTH WALES.

Section of Well at Kelsterton Brewery Co.'s, Flint.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well	9	—	—	—
Rock	195	—	—	—
Rock	—	—	204	—

Lined with 55 feet of 7¼-inch tube, 2 feet below surface. Supply touched at about 130 feet below surface. Water level, 7 feet from surface. Supply good.

Section of Well-boring at King's Head Hotel, Holywell, Flint.

Collected by the Cardiff Naturalists' Society.

—	Feet	Inches	Feet	Inches
Dug well	60	—	—	—
Green sand	5	—	65	—
Sand and pebbles	13	—	78	—
Rock	18	6	96	6
Rock and sand	3	6	100	—
Rock	—	6	100	6

Lined with 30 feet of 4-inch tube, top of which stands 55 feet below surface. Supply good. Water supply overflows top of bore-pipe. Supply tapped at about 89 feet from surface.

Section of Well at A. J. Chadwick's, Esq., Burton Brewery, Wrexham.
4-inch Boring.

Collected by the Cardiff Naturalists' Society.

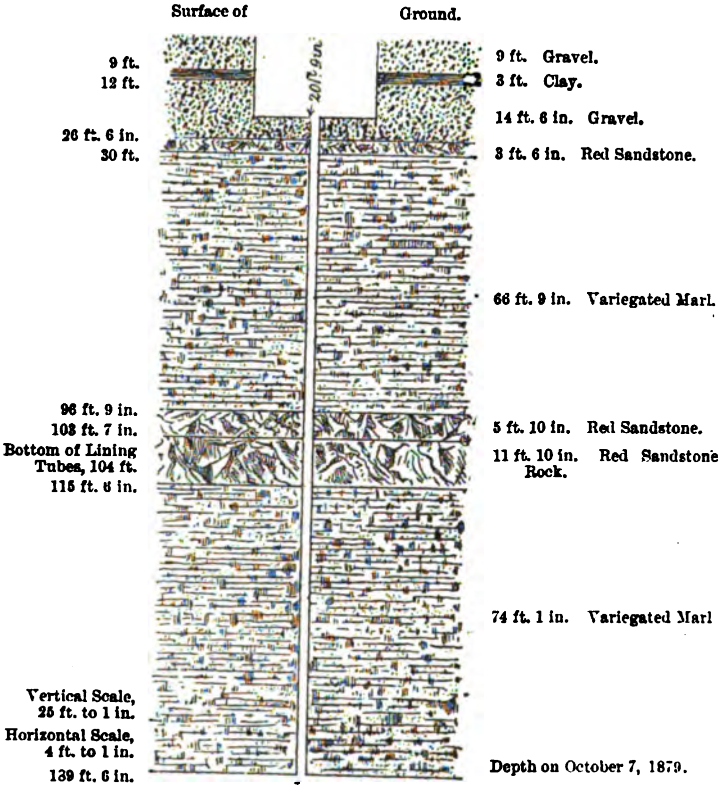
—	Feet	Inches	Feet	Inches
Dug well	4	—	—	—
Red sand	25	—	29	—
Red clay	10	—	39	—
Blowing sand	11	—	50	—
Brown sand	32	—	82	—
Blowing sand	21	—	103	—
Brown clay	8	—	111	—
Blowing sand	36	—	147	—
Red clay and pebbles . . .	17	—	164	—
Rock	4	—	168	—
Stones and clay	9	—	177	—
Stone	6	—	183	—
Stones and clay	18	—	201	—
Clay	22	—	223	—
Stones and clay	39	—	262	—
Clay	14	—	272	—
Stones and clay	12	—	284	—
Clay	47	—	331	—

Lined with 280 feet of 4-inch tubing. Water level 3 feet from surface. Supply, 8 gallons per minute. Water first touched at 162 feet, when artesian level was 14 feet from surface.

Collected by C. E. DE RANCE from Dr. LLOYD ROBERTS, Medical Officer of Health, Denbigh.

Pont Ystrad Pumping Station.
Well 20 feet 9 inches deep.—Denbigh Water Company.

FIG. 1.—Pont Ystrad Pumping Station. Section of Well and Bore-hole.


Surface of Ground.
20 ft. 9 in.
9 ft.
12 ft.
26 ft. 6 in.
30 ft.
96 ft. 9 in.
103 ft. 7 in.
Bottom of Lining Tubes, 104 ft.
115 ft. 6 in.
Vertical Scale, 25 ft. to 1 in.
Horizontal Scale, 4 ft. to 1 in.
139 ft. 6 in.
9 ft. Gravel.
3 ft. Clay.
14 ft. 6 in. Gravel.
3 ft. 6 in. Red Sandstone.
66 ft. 9 in. Variegated Marl.
5 ft. 10 in. Red Sandstone.
11 ft. 10 in. Red Sandstone Rock.
74 ft. 1 in. Variegated Marl
Depth on October 7, 1879.

Analysis made by Dr. CAMPBELL BROWNE, *April* 14, 1882.

	Parts per 100,000.
Total solids in solution	20·4
Organic carbon Organic nitrogen } (Traces only)	
Ammonia	·003
Ammonia from organic matter, by distillation with alkaline permanganate	·009
Nitrogen, as nitrates and nitrites	·069
Combined chlorine	2·059
Hardness, temporary	7·5°
„ permanent	6·0°
Total	13·5°

This is an excellent water for domestic use.

Bore-hole at Pont Ystrad.—Denbigh Water Company.

Analysis made by Dr. CAMPBELL BROWNE, *November* 1, 1879.

Mark of sample:	B.	W.
	Parts per 100,000.	
Total solids in solution	85·0	34·4
Organic carbon Organic nitrogen } Traces only in each		
Ammonia	002	·003
Ammonia from organic matter, by alkaline distillation	·004	·005
Nitrogen, as nitrates and nitrites	·000	·04
Combined chlorine	2·84	3·55
Hardness, temporary	15·12°	7·0°
„ permanent	31·78°	14·2°
Total	46·90°	21·2°

'B.' contains a larger proportion of mineral salts than is usual in even the hardest water used for domestic supply, but there is nothing injurious in these salts except that they waste soap and prevent the water from cleansing the skin even with a great quantity of soap, as well as from cooking such things as tea without great waste.

There is no organic matter and no products derived from any previous sewage contamination; it is free from common salt.

'W.' is not quite so free from organic matter, but the quantity of organic matter derived from it is very small.

The hardening salts and the other mineral salts are within ordinary limits.

As a general rule the deep bore waters are safer than upper waters.

Deep Bore-hole Water. Pentre Meadows, Llanrhaiadr.

Analysis made by EGBERT G. HOOPER, *Esq., F.C.S., of Somerset House, April* 7, 1888.

Organic matter: very slight in quantity.
Physical properties: neutral, bright and clear, tasteless and odourless.

	Grains per Gallon.
Total solids	14·0
Loss on ignition	4·0
Mineral matter	10·0
Hardness, permanent	3·5°
„ total	7·0°

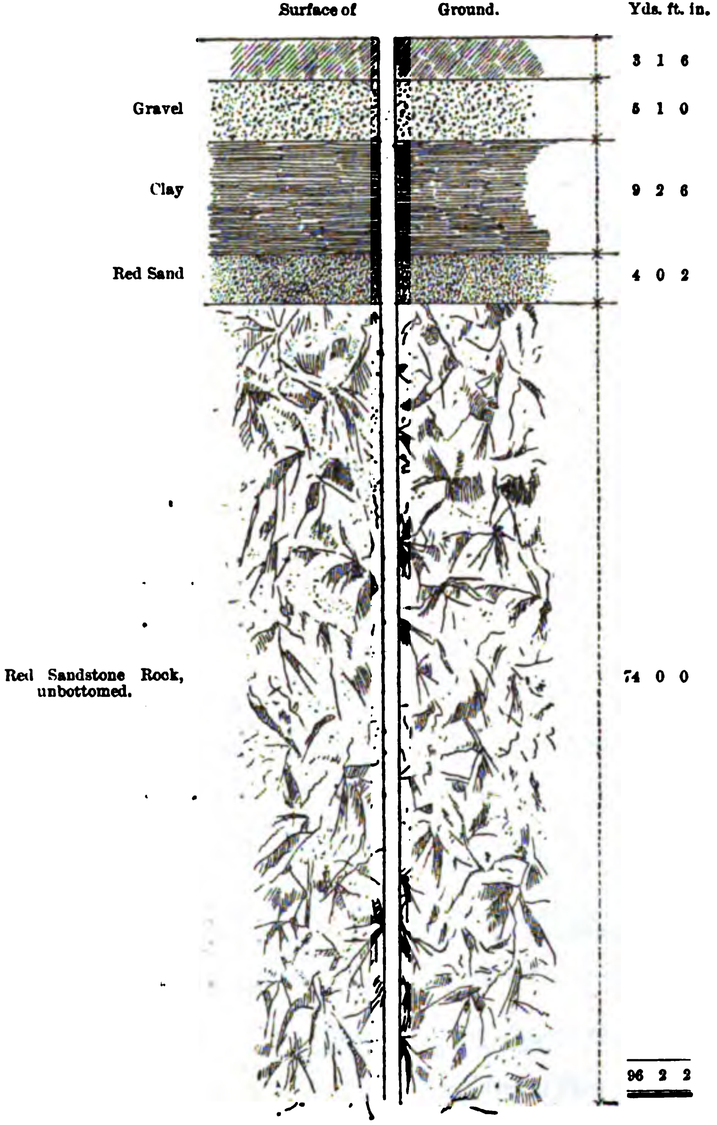
Nitrates and nitrites (absent)
Ammonia, free (none)
„ albuminoid ·004 part per 1,000,000
Chlorides equal to 1·81 grain of common salt per gallon

Mineral constituents:	Grains per Gallon.
Chalk	5·80
Magnesium sulphate	1·03
„ carbonate	0·56
Common salt	1·81
	9·20

This water is one of the purest commonly found, and with care to avoid surface contamination would be most suitable for domestic and for table use. For brewing purposes, however, and especially for ale-brewing, it is too soft, and therefore cannot be recommended, though for stout-brewing it would offer some advantages, and should a suitable supply not be obtainable additional hardness might be added to the water artificially.

FIG. 2.—Section of Llanrhaiadr (Pentre Meadows) Bore-hole.

June 14, 1875.



There is some slight evidence of organised impurity, indicating admixture, to a small extent, with surface water, which would need to be guarded against if the supply were adopted.

Prestatyn Wells. *Analysed by* Dr. Lloyd Roberts, *August* 10, 1888.

Smithy Well, Prestatyn.

A surface (dip) well.

	Parts per 100,000.	Grains per Gallon.
Total solids	124·4	87·22
„ after ignition	62·4	43·68
Chlorine	11·2	7·8 = 14·8 of NaCl
Free ammonia	part per 1,000,000	·130
Albuminoid ammonia		·390
Nitrates Nitrites	Very evident traces.	

	Parts per 100,000.
Hardness, temporary	24
„ permanent	17
Total	41 = 28·7 grains per gallon.

Rectory Well (Pump), Prestatyn.

Chlorine: 6·4 parts per 100,000 = 4·48 grains per gallon.

	Parts per 100,000.
Hardness, temporary	12
„ permanent	18
Total	30

Nant Hall Pump, Prestatyn.

	Parts per 100,000.
Hardness, temporary	25
„ permanent	19
Total	44

Nant Mine Overflow, Prestatyn.

	Parts per 100,000.
Hardness, temporary	14·0
„ permanent	14·0
Total	28·0

Plas Newydd, Trefnant.

A surface (dip) well, in red sand.

	Parts per 100,000.
Hardness, temporary	4·0
„ permanent	20·0
Total	24·0

Bronwylfa Garden, St. Asaph.

Surface well, in red sand.

Deep Well at Hafod-y-Green, Trefnant.

About 90 feet deep.

Analysis made by Dr. CAMPBELL BROWNE, *December* 15, 1877.

	Parts per 100,000.
Total solids	148·0 (including Fe and sulphates)
Ammonia	·004
Ammonia from organic matter by alkaline distillation	·028
Nitrogen, as nitrates and nitrites	·46
Combined chlorine	27·5 = 45·32 grains of common salt
Total hardness	46·0

This water contains a little organic matter and the remains of oxidised animal matter of some kind; but the quantity is not large, and probably the water might be easily kept sufficiently pure so far as these constituents are concerned. It contains a very excessive proportion of common salt, and a considerable proportion of chloride of calcium and sulphate of calcium and other phosphates. If this can be accounted for by the infiltration of sea water through the sand, or by the occurrence of salt deposit in the rock, the saltness may be considered not to affect the wholesomeness of the water; if the saltness cannot be accounted for in this way the water must be considered a suspicious one.

SHROPSHIRE.

Collected by Mr. THOS. A. STOOKE, *C.E.*

1. At the Shropshire and Montgomery Counties Lunatic Asylum, Bicton, near Shrewsbury. **1***a*. In 1891 and 1892. **2.** 267 feet above Ordnance Datum. **3.** Depth of well 117 feet, diameter 6 feet. Depth of bore-hole 190 feet, diameter 8 inches. **3***a*. 107½ feet to the top of Storage Heading; length, 31 feet; contents, 11,400 gallons. **4.** Water stands about 105½ feet below the surface before pumping, and is lowered about 2 feet when the usual day's supply is pumped. The ordinary water level is restored in about three hours. **4***a*. 106 feet was the point of water level in the well; but when the bore-hole was put down the level was raised nearly 1 foot in the well, to which point it barely rises now. **5.** In May 1893 the duplicate engines and pumps were worked together, pumping off 7,200 *gallons per hour*, at the rate of 172,800 gallons in the twenty-four hours, with the following results, the valve controlling the supply from bore-hole being fully open, viz.—

	Ft.	in.
With 4 hours' pumping the depth of water was	4	9
„ 6 „ „ „	4	3
„ 9 „ „ „	4	0
„ 10 „ „ „	4	0

No further reduction in the water level was made. The average quantity pumped is about 45,000 gallons daily. **6.** Only as before referred to Query 4*a*. **7.** Not affected by rainfall. The water stands about 5 feet above the summer flow of the River Severn. **8.** Analysis by Mr. Blunt, Public Analyst for Shropshire:—

	Grains per Gallon.
Solids in suspension (none)	
Solids in solution dried at 140° C.	22·0
Oxygen absorbed in four hours at 15° C.	0·014
Saline ammonia	0·003
Albuminoid ammonia	0·0055
Nitrogen in nitrates	0·26
Nitrites (none)	
Chlorine in chlorides	1·45
Hardness, temporary	11½°
„ permanent	6½°
Total	18·0°

An approximate analysis of solids gives the following results:—

	Grains per Gallon.
Carbonates of alkaline earths, principally lime	16·0
Sulphate of magnesia	3·6
Chloride of sodium	2·4
	22·0

This is an excellent drinking water, free from all trace of animal contamination; it is, perhaps, a little hard for general purposes, as is the case with all the water of the district. Water used for laundry purposes is softened.

	Ft.
9. Yellow clay with pebbles	9
Sandy red clay	4
Sandy gravel	3
Sandy grey and red loam	19
Coarse gravel	3
Red sandstone rock (Bunter beds)	55
Grey „ „	6
Red „ „	91
	190

9a. A steadily increasing yield of water was met with from 106 feet. The greatest increase was from the bore-hole below 150 feet, which caused the water level to rise in the well. **10.** Yes. **11.** Yes, the well is lined with iron cylinders to the depth of 85 feet. **12.** The Permian measures outcrop about 700 yards south of the site. **13.** No. **14.** No. **15.** An old well under the asylum buildings has been abandoned and filled in on account of the surface water finding its way into it.

Collected by Mr. Thos. A. Stooke, *C.E., Shrewsbury.*

1. Hinnington, on the Hatton Estate, about 2½ miles south of Shifnal, Salop. **1a.** Tube wells driven in 1889. **2.** 172 feet O.D. approximately. **3.** Three 2-inch tube wells are driven to the depth of about ten feet, and connected by a horizontal pipe under the ground surface. **3a.** —. **4.** Water stands about two feet under the surface of the ground outside the tube. **4a.** Wells; it is lowered only ⅜ths of an inch while pumping. On ceasing to pump the ordinary water level is at once restored. **5.** The yield of water flowing freely through the pipe connecting the tube wells together was found to be 64,800 gallons in the twenty-four hours. Pumping into a storage reservoir containing 30,000 gallons takes place twice during the week; the daily consumption is about 3,000 gallons. **6.** Water level does not vary, **(7)** and is not affected by rainfall. **8.** Analysis.

	Grains per Gallon.
Total solid contents	13·0
Chlorine in chlorides	0·95
Nitrogen as nitrates	0·08
Oxygen absorbed	0·009
Total hardness	10·5

'A pure and excellent water both for drinking and general domestic use.'

9. Section gave 18 inches of soil with a little clay, and a sharp white and red sand on (**9a**) the Bunter series of the New Red Sandstone. **10.** No. **11.** **12.** The Permians outcrop about one mile on the west. **13.** No. **14.** No. **15.** No. **16.** Wells on the north-east of the estate, after being deepened on several occasions, have been abandoned on account of the steadily decreasing water levels in the Bunter beds, occasioned by the pumping operations at the Cosford well and bore-hole of the Wolverhampton Corporation Water Works.

Messrs. Walker's Works, Donnington, Salop. Particulars received from Messrs. TIMMINS & SONS, *Bridgwater Ironworks, Runcorn.*

1. At Messrs. C. and W. Walker's works, Donnington, Salop. **1a.** Well deepened and bore-hole put down May 1886. **2.** Approximately 230 feet O.D.

	Ft.	in.		Ft.	in.
3. Depth of well	30	0	Diameter	4	3
Depth of bore-hole	234	0	"	0	6
" "	302	4	"	0	4

3a. No drift ways. **4.** Natural water level 26 feet under the surface. **4a.** No record. **5.** 27,648 gallons in twenty-four hours. **6.** Not known to have diminished.

	Ft.	in.
9. Red sandstone to about	135	0
Soft loamy sandstone, requiring casing tubes	167	4
	302	4

	Gallons in 24 Hours.
9a. The yield of the well alone	500
With bore-hole at the depth of 212 feet . .	5,760
On the completion of bore-hole	27,648

NOTTINGHAMSHIRE.

The Worksop Waterworks Co.

Collected by MR. TYLDEN WRIGHT.

1. Worksop, Notts. On a hill north of the town. **1a.** 1876. No. **2.** 200 feet. Ordnance map. **3.** Well 150 feet deep, 5 feet diameter; 365 feet from surface to bottom of bore hole, 10 inches diameter. **3a.** No drift ways. **4.** 180 feet before pumping, 145 feet after pumping. 1 hour. **4a.** No record. **5.** 300,000 gallons. 190,000 gallons daily quantity. **6.** Slightly; the supply is better in *summer than in winter*. **7.** No.

	Per Million Gallons.
8. Free ammonia	·0375
Ammonia from organic matter	·0475
	Grains per Gallon.
Chlorine	2·53
Dissolved mineral matter	30·00
Hardness, temporary	7°
" permanent	14°
Total . .	21°

10. No drift. **11** to **15.** No.

New Town, Backwell, Mr. Bagnot's Brewery. Made and communicated by Messrs. DOMRA.

Collected by Mr. W. WHITAKER, F.R.S.

Dug 5 feet, the rest bored.

—	Thickness	Depth
	Ft.	Ft.
Red marl	47	47
Hard red sandstone	1½	48½
Red marl, with veins of grey	55½	104
Hard grey stone	2½	106½
Red marl	1	107½
Grey stone	1	108½
Red marl	1	109½
Grey stone	1	110½

LINCOLNSHIRE.

Particulars of Bore-holes.

Collected by C. E. DE RANCE from Mr. E. C. B. TUDOR, C.E., Goole.

1. Hook Road, at N.E.R. cottages. Total depth, 200 feet; 4-inch bore-hole for domestic supply. Warp.—Blue marl, with gypsum (Keuper marls). Surface level about 10 feet above the Ordnance Datum; bottom of boring 190 feet below it.

2. Armin, village supply, boring 200 feet; all in soft New Red sandstone. Surface level about 10 feet above O.D.; bottom of bore-hole 190 feet below it.

3. Booth Ferry Road, Goole Local Board, 6-inch trial bore, 366 feet deep. Probably the first 28 feet was drift, the remaining beds being sands and sandstones, with 80 feet of marls in six beds. The surface level is 10 feet above O.D., and that of the bottom of the bore-hole 356 feet below it.

4. Rawcliffe Bridge, Goole supply. Well 60 feet deep, 10 feet diameter. No boring works were commenced in 1882. The engine-house floor is level with the canal, which is 11·5 feet above O.D. The water stands at 28 feet below the surface, and at 40 feet after 24 hours' pumping, or 17 feet and 29 feet below O.D. respectively. Before any pumping took place it stood at 22 feet from the surface, or 11 feet below O.D. The average quantity of water pumped is a quarter of a million gallons; working the two pumps double that quantity can be lifted.

4*a*. Pulp Works, about 400 yards to N.E. Well-boring 300 feet deep, of 12 inches diameter, in red sandstone. Yield 1¼ million gallons per day, which lowers the water level of No. 4 3 feet. Level above O.D. about 12 feet.

5. New Bridge, near Snaith. Goole Local Board trial boring, 500 feet, with 6-inch diameter. The boring is about 17 feet above O.D., the bottom 483 feet below it. The section in abstract is as follows:—

		Feet.
46	feet brown warp, peat, and loam	46
51	„ gravel, magnesia limestone fragments	5
500	„ red marly sand and variegated marls	449

Of the red measures 32 feet consist of coarse red sand, 11 feet of variegated marls, the balance of marly sands; the whole I regard as belonging to the Keuper Waterstones, and call the 'Goole Beds.' They appear to be part of the series found at the Booth Ferry Road, and if so the beds must be repeated by a fault; but, if so, the latter can have no great north and south range, for if it had no water from the west could pass through it, and no water would be found at Rawcliffe and Goole. But it is quite possible that an east and west fault, with a southerly downthrow, ranges through the district, and may be connected with the fault at Addy Wood in the Permians, or these beds may be thrown in by a very local trough fault, which view is supported by the small supply of water met with.

6. East Cowick. Village supply. Boring 4 inches diameter, 90 feet deep. Through 'pan sand' (drift sand cemented by oxide of iron) and very soft red sandstone. Water good. Surface level 20 feet above O.D., bottom level 70 feet below O.D.

7. West Cowick. Village supply. Depth, diameter, and section same as No. 6. Surface level 25 feet above O.D. Site close to 'Bay Horse Inn.'

8. West Cowick. Trial boring N.N.W. of No. 7. Surface level, 25 feet above O.D.; depth, 80 feet. Marl, &c., here pointing to some disturbance.

9. West Cowick. Hartley's Brewery. Surface level, 25 feet above O.D.; depth, 1,050 feet; bottom level, 1,025 feet below O.D.

Section (1,050 feet) :—	Feet.
Red gravel	55
Red sandstone	623
Beds not reported	372

Total hardness of water, 14·0°.

10. South Field. Trial boring for Goole supply, south of Park House Farm. Surface level, about 15 feet above O.D.; depth, 152 feet; level of bottom of bore-hole, 137 feet below O.D. Water stated to be good.

10*a* and **10*b*.** Trial borings for Wakefield Corporation, west of Heck railway station, where the sandstone rock is visible. Surface level, 40 feet and 50 feet above O.D. The late Dr. Letheby reported as follows on these samples, on October 22, 1875. Sample A, bore-hole in Mr. Drewer's land, taken at 12 P.M., September 16, 1875; Sample B, from No. 2 bore-hole, taken October 13, 1875:—

Grains per Gallon	Sample A	Sample B
Actual ammonia	·0002	·0001
Ammonia from organic matter	·0000	·0002
Nitrogen, or nitrates	·0735	·0585
Total solids	19·30	13·33
Hardness—temporary	14·3°	10·0°
„ permanent	7·0°	6·0°

This water is thoroughly free from organic impurity and of moderate hardness, and in every way thoroughly suited to be a source of public water supply.

11. Pontefract Water Supply Well. One mile S.W. of Aire, at Chapel Haddlesey, which is the highest point to which the tide flows. Surface levels, 25 feet above O.D.

Dr. Franklin Parsons, of the Local Government Board, was good enough, in February 1892, to give some very valuable information to the Committee as to the quality of the water of the Goole district, from which report the following abstract has been made:—

The water from the red sandstone at Goole is of a peculiar character, containing a large amount of free ammonia, of solid matter and soap-destroying salts, chiefly magnesia and iron in a ferrous state; though clear at first, it afterwards throws down a rusty sediment, at the same time losing its chalybeate taste and smell, which at first is very apparent. At Selby, and to a less extent at Rawcliffe, this is not the case; and he points out that, in the first case, the sandstone is covered with impermeable clays; in the second, the gathering ground is either bare rock or rock covered with porous gravels; and justly observes that the water in the red sandstone is 'aërated in one case and not in the other.'

Water from Booth Ferry Road—Trial Boring.

Date	Aug. 12, 1875	Sept. 16, 1875	Oct. 30, 1875	Nov. 8, 1875	Nov. 29, 1875	Nov. 30, 1875
Depth	96 feet	?	300 feet	—	366 feet	—
Character	Rusty sediment	Becomes turbid	Ditto	Ditto	—	—
Free ammonia	·62 per million	·83	1·40	1·19	2·40	1·94
Albuminoid ammonia	·08 „	·035	·05	·05	·055	·03
Hardness, total	20·0	—	21·0	24·0	26·0	24·5
„ permanent	10·0	—	8·5	10·5	12·0	12·5
Total solids	33·0	36·0	32·5	33·0	37·0	33·0
Chlorine	1·5	1·1	1·2	1·2	1·4	1·4
Nitric acid	—	—	—	—	—	—
Iron	Much	—	0·4	—	Much	0·4
Sulphuric acid	Moderate	—	—	—	—	—

The last sample gave 12·5 grains per gallon of carbonate of magnesia.

At Rawcliffe Station Well samples taken September 16, 1875, showed the same chalybeate taste and smell which obtains at Goole, but the quantity of ammonia is less, thus:

	Per Million Parts.
Free ammonia	·03
Albuminoid ammonia	·03

The hardness is also less, the total being 12·5, and permanent only 4·5. The total solids were only 30 grains per gallon, but the chlorine is 2·3.

At Rawcliffe Hall Well, 250 feet in the New Red Sandstone, the temperature of the water is 51°; it has no taste or smell, and only contains 27 grains of solids to the gallon.

At Selby Waterworks a sample of water taken July 27, 1874, yielded the following:—

	Per Million Parts.
Free ammonia	·03
Albuminoid ammonia	·025
Hardness, total	9·5°
„ permanent	4·5°
Chlorine	2·1[1]

These results establish the fact that on approach to the outcrop of the New Red Sandstone there is direct increase of purity, both as regards ammonia, total solid impurity, and amount of hardness, and they agree with the results of Dr. Letheby, at Heck, taken a month later in the same year.

BERKSHIRE.

New Lodge, Windsor Forest. Professor HULL, F.R.S.

		Feet.
TERTIARY.	Bagshot Sand London Clay	214
CRETACEOUS.	Chalk	725
	Upper Greensand	31
	Gault Clay	264
	Lower Greensand	7
	Total	1,241

Very little water was struck till the borer reached the Lower Greensand, when it came up with great force, 7 feet above surface of ground. The position is very near the centre of the London Tertiary Basin, and the level about 230 feet above O.D., but of this I am not quite certain.

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[1] For section of this well see reprint of author's papers in *Proc. of Yorks. Polytechnic and Geological Society.*

WILTSHIRE.

Boring at Gas Works, Fordingbridge, Salisbury, 1887, *by* Messrs. TILLEY.

Details furnished by Messrs. TILLEY and E. WESTLAKE, F.G.S.

—	Thickness in Feet	Depth in Feet
Soil—		
Black mould	2	—
River gravel—		
Broken subangular gravel in a good deal of sand.	12	14
Lower Bagshot (Base of ?)—		
Fine grey quartz sand, clayey in places	6	20
London clay, 118 feet—		
Grey sandy clay	8	28
Sand and pebbles	2	30
Hard stiff clay	10	40
Sand, with pebbles at the base	4	44
Sandy clay	6	50
Septarium containing fossils, *Turritella imbricataria*, &c.	1	51
Clay	8	59
Hard stone	1	60
Dark clay	7	67
Dark clay with shells, probably *Pholadomya*	3	70
Dark bluish clay	14	84
Hard stone	½	84½
Dark bluish clay with a few small pebbles—*Cardita planicosta*, *Rostellaria lucida*, Sow., *Turritella imbricataria*	7	91½
Hard stone	½	92
Clay	8	100
Brown clay, very hard and compact	4	104
Septarium (met with at same depth in both borings)	1½	105½
Sand and clay, with water under the stone	20	125½
Sand and water	3	138½
Sandy clay	7	135½
Sand, shale, and pebbles (Basement bed ? Doubtful if pebbles are more than 6 inches thick)	3	138½
Reading Beds, 74 feet—		
Light grey clay laminated with grey sand	6	144½
Greenish-brown loam with a little glauconitic sand and lignite.	11½	156
Buff-coloured calcareous stone, 4 inches	¼	156¼
Light brown clay	3¾	160
Brown clay	2	162
Mottled clay, 31 feet—		
Whitish-grey or pale green clay, with occasional streaks of red	14	176
Light grey pipe clay	1	177
Red clay	3	180
Yellow clay, greyer towards the base	8	188
Dark-brown or chocolate-coloured clay	2	190
Purple clay streaked with ochre	3	193
Marl, 9 feet—		
Pale bluff-coloured marl	3	196
White highly calcareous marl	4	200
Pale green or olive-coloured marl with small calcareous lumps	2	202
Greensand (glauconitic quartz and iron grains) with *oyster* shells	10	212
Chalk	7	219

Level of ground 88 feet above Ordnance Datum. Water from the sand at 125 feet rose to 13 feet above the ground. The flow of water is about 2,000 gallons per day. No appreciable additional quantity of water was obtained from the Reading Beds or from the Chalk, and the pipes were withdrawn to the base of the London Clay.—(E. W.)

List of Queries circulated.

1. *Position* of well or shafts with which you are acquainted ?

1*a*. State *date* at which the well or shaft was originally sunk. Has it been deepened since by sinking or boring, and when ?

2. Approximate *height* of the surface of the ground above Ordnance Datum (mean sea level) ?

3. *Depth* from surface to bottom of shaft or well, with diameter. *Depth* from surface to bottom of bore-hole, with diameter ?

3*a*. *Depth* from the surface to the horizontal drift-ways, if any ? What is their length and number ?

4. *Height* below the surface at which water stands *before* and *after* pumping. Number of hours elapsing before ordinary level is restored after pumping ?

4*a*. *Height* below the surface at which the water stood when the well was first sunk, and height at which it stands now when not pumped ?

5. *Quantity* capable of being pumped in gallons per day of 24 hours ? Average quantity daily pumped ?

6. Does the *water level* vary at different seasons of the year, and to what extent ? Has it diminished during the last ten years ?

7. Is the ordinary *water level* ever affected by local rains, and, if so, in how short a time ? And how does it stand in regard to the level of the water in the neighbouring streams or sea ?

8. *Analysis* of the water, if any. Does the water possess any marked *peculiarity* ?

9. *Section*, with nature of the rock passed through, including cover of drift, if any, with *thickness* ?

9*a*. In which of the above rocks were springs of water intercepted ?

10. Does the cover of Drift over the rock contain *surface springs* ?

11. If so, are these *land springs* kept entirely *out* of the well ?

12. Are any large *faults* known to exist close to the well ?

13. Were any *brine springs* passed through in making the well ?

14. Are there any *salt springs* in the neighbourhood ?

15. Have any wells or borings been discontinued in your neighbourhood in consequence of the water being more or less *brackish* ? If so, please give section in reply to query No. 9.

16. Kindly give any further information you can.

The Eurypterid-bearing Deposits of the Pentland Hills.—Second Report of the Committee, consisting of Dr. R. H. TRAQUAIR (*Chairman*), Professor T. RUPERT JONES, *and* Mr. MALCOLM LAURIE (*Secretary*). (*Drawn up by the Secretary.*)

DURING the past year a considerable amount of time has been spent in developing the material already acquired. The grant of money was chiefly expended in securing the assistance of Mr. Henderson, the original discoverer of these fossil beds. Thanks to his able assistance a considerable part of the material has been worked over with very satisfactory results, though much yet remains to be examined.

The specimens already obtained include five species of Eurypteridæ belonging to four genera. One of these, a specimen—unfortunately badly preserved—of *Pterygotus*, is new to this locality, and is in all probability new to science. It is allied by the form of the telson to *Pt. anglicus* from the Old Red Sandstone rather than to the common Silurian form *Pt. bilobus*. It is the first species with a pointed telson from the Silurian, of this country, though this form of telson has been described by Pohlmann from the Buffalo Limestones of America.

The genus *Eurypterus* is also only represented by a single specimen, which, though much larger than the type specimen, I am inclined to refer to *Eurypterus conicus*.

Stylonurus ornatus, the large form from these beds, is represented by a considerable number of specimens, mostly fragmentary. One specimen shows the body minus the carapace and telson to have been 10 inches in length. The details of a number of the appendages have been made out, including the two posterior pairs which are the long walking legs characteristic of the genus. The posterior of these has a length of 9 inches, the anterior of about 7½ inches. In front of these two appendages I have made out representatives of two other pairs of limbs, both of which are furnished with long spines. The detailed description of these and other points of interest must, however, be postponed till a more thorough investigation has been made.

The other species of *Stylonurus* which occurs in these beds—*St. macrophthalmus*—is well represented. One specimen is almost complete, only wanting the telson and part of one side of the body. It shows four appendages down one side. The two posterior limbs are more unequal in size than is usual in this genus, the anterior one being far more slender than the posterior and only two-thirds its length. The appendages in front of these do not appear to be so well furnished with spines as in *St. ornatus*. Another specimen of this form, though very fragmentary, has shown, after careful development, five legs down one side of the carapace. They have not yet, however, been fully worked out. There are various other fragments, showing parts of the body, tail spines, &c.

Of the other form occurring in these beds, *Drepanopterus pentlandicus*, we have been fortunate enough to secure one almost perfect specimen, which shows the form of the body and three pairs of limbs. The form of the last pair of limbs but one confirms the relationship of this form to *Stylonurus*. There are many other more or less fragmentary specimens, which may be expected to yield further information as to the details of this interesting genus.

Besides the Eurypteridæ the bed has yielded a considerable number of other fossils, among which may be mentioned: Graptolites, various Polyzoa, a species of Gomphoceras, Lingula and other brachiopods. These, when properly identified, may be expected to yield important information as to the exact horizon of the beds.

In view of the large amount of material which yet remains to be examined and the interest of the results which are briefly referred to above, your Committee ask to be continued for another year with a further grant.

Stonesfield Slate.—Report of the Committee, consisting of Mr. H. B. Woodward (*Chairman*), Mr. E. A. Walford (*Secretary*), Professor A. H. Green, Dr. H. Woodward, *and* Mr. J. Windoes, *appointed to open further sections in the neighbourhood of Stonesfield in order to show the relationship of the Stonesfield Slate to the underlying and overlying strata.* (*Drawn up by* Mr. Edwin A. Walford, *Secretary.*)

The basement beds of the Great Oolite in the Midlands and in the south-west counties of England have been hitherto supposed to be well defined. For in all the records of the many writers on this geologic subdivision, to the Stonesfield Slate has been assigned the line of separation from the Fuller's Earth or Inferior Oolite, or, where the Stonesfield Slate is absent, as in the extreme west, to the Minchinhampton beds has been given the same position. Undue prominence has been given to so inconstant a series of beds as the Slate, as much from the ease with which fossils for its study have been collected as from the varied character of the fauna and flora found in it. From the days when the finding of the mammalian remains in the Slate called the attention of geologists prominently to it, every text-book of geology has found a place for it at the bottom of the Great Oolite limestones. Though, however text-books and papers have defined the lower boundary of the Great Oolite so clearly, the officers of the Geological Survey in their work in the neighbourhood of Stonesfield found the lines so difficult to define that it became necessary, where the Slate had disappeared, to adopt an intermediate colouring, a kind of no-man's-land. Since then an argillaceous stratum, 'the Rift bed,' has been recognised as the lowest of the Great Oolite beds in the Banbury and Hook Norton area.

The endeavour of the work, for which the British Association made a money grant in 1893, has been to ascertain the thickness and composition of the beds underlying the Slate, for hitherto no account of these beds has been obtainable, Professor Ed. Hull's record [1] of 70 feet being the only assumed thickness of the Great Oolite, and to this he adds 30 feet for the Inferior Oolite. Though their thicknesses seem to be over-estimated, no correction or account of a series of rocks so important has since then been written. Nearer Chipping Norton, however, Mr. J. Windoes, Mr. W. H. Hudleston,[2] and your Secretary [3] have worked at some of the debatable beds above the Clypeus grit, one of the highest of the Cotswold divisions of the Inferior Oolite. To the bulk of these beds has been given the name of the 'Chipping Norton Limestone' by Mr. Hudleston,[2] and though the beds have not been reached in the section, they may be seen in the lane sections and near the spring on the banks of the Evenlode, south of Stonesfield. Your Secretary in 1892-93 sank a shaft near Ditchley, Oxon, to find out the true position of the Slate beds there; but of this an account will be published elsewhere.

The progress of the work, so far, at Stocky Bank, Stonesfield, has consisted in scarping the bank for 33 feet, and in continuing the section by carrying a shaft of 20 feet in depth through the lower bank. The purpose of the work has been so far successfully carried out by showing the existence of 30 feet of rock with some thin clay courses below the Slate. These limestones and clays (see accompanying section on p. 306) are of Great Oolite type. To reach the Clypeus grit will need an extension of time.

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[1] *Report Brit. Assoc.*, 1860, p. 82 (Sectional Proceedings).

[2] W. H. Hudleston, *Proc. Geol. Assoc.*, vol. v. No. 7.

[3] E. A. Walford, 'On the Relation of the so-called Northampton Sand of N. Oxon to Clypeus Grit,' *Q.J.G.S.*, vol. xxxix. p. 235.

Your Secretary has, by the discovery of numerous species of corals on the ploughed fields on the bank top, been able to define the coral bed (Rift bed)[1] so prominent a feature in the near section at Ashford Bridge. Seventeen feet below the coral bed a course of Slate is met with, almost thinned out at that point, and only from 5 to 7 inches in thickness; the total thickness of it and the associated beds (10, 12, 13 of the section) being about 5 feet. The usual fossils, *Trigonia impressa*, &c., occur. In the lower limestones, 15 and 17, are greenish clay inclusions.

The great mass of buff limestone below the slate is almost unfossiliferous, and neither its mineralogical character nor its few fossils give sure evidence of its relationship to neighbouring beds.

Prominent in the lower half of the section is the breaking up of the calcareous series by small clay beds, and of these No. 23, with its dark compact clays, is in part made up of oyster-shell fragments. It contains numerous compressed shells, *Perna quadrata*, *Nucula*, &c., but washings of the beds yield hardly any microzoa. The limestone above the clay yields well-known Great Oolite shells, *Mytilus Sowerbyanus*, *Rhynchonella concinna*, and *Ostrea Sowerbyi*. The shelly limestone below the clay is in part an Oyster lumachelle, and passes into a blue-hearted limestone with *Perna quadrata*, large *Cyprinæ*, *Corbula*, and *Macrodon*. Here, again, both petrological facies and fauna are dissimilar to any of our known Oxfordshire Oolitic rocks, and, like each of the succeeding lower beds, should be classed as Great Oolite; one of the latter, a hard very oolite freestone, has also as distinctive a character.

In conclusion, it should be stated that though, when Professor Ed. Hull reported to your Association at its Oxford meeting, thirty-four years ago (1860), the presence of seventy feet of Great Oolite limestone under the Stonesfield Slate, it seemed to be an over-estimate, yet the result of the present investigation has been to prove the presence of an important and overlooked section of the Great Oolite, and to entitle place for it in future accounts of that subdivision. That Professor A. H. Green doubted the existence of so great a series of beds as those quoted by Professor Hull is proved by the absence of any account of them in his excellent memoir 'On the Geology of the Country round Banbury, Woodstock, Bicester, and Buckingham,' published in 1864.

Mr. James Windoes, Mr. Wilfred Hudleston, Mr. H. B. Woodward, and your Secretary have also worked in later years at the determination of the equivalent of these lower Bathonian beds in the neighbourhood of Chipping Norton.

To his Grace the Duke of Marlborough, to the Right Hon. Lord Dillon, to Mr. John Barrett of Stonesfield, and to Mr. S. Shilson of Charlbury, the thanks of your Committee are due for aid in this and other relative work.[2]

The probable extension of a lower division of the Great Oolite below the limit reached by us, large enough with that already discovered to entitle it to a place as a sub-formation, makes a continuance of the work a necessity for the right understanding of the lower Jurassic rocks of Great Britain.

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[1] E. A. Walford, *Q.J.G.S.*, vol. xxxix. p. 230.

[2] Mr. R. F. Tomes has kindly named the corals.

Section at the S.W. end of Covert, Stocky Bank, Stonesfield, Oxon, 1894.

		Ft.	In.
1.	Humus with limestone fragments containing *Nerinæa*, *Cryptocœnia Prattii* E and H, *Cryptocœnia* sp., *Isastræa microphylla* Tomes, *Isastræa limitata* Lamx., *Isastræa* near to *limitata* Lamx., *Thamnastræa Lyelli* E and H and *Epismilia* sp. 'RIFT BED'	0	9
2.	Grey Marls with *Ostrea*, *Placunopsis*, and *Rhynchonella concinna*	4	0
3.	Fawn-coloured Sands and Marls—oyster bed	2	0
4.	Grey shelly compact Limestone weathering cream-coloured	6	0
5.	Hard grey Marls with *Rhynchonella concinna*	0	9
6.	Shelly Limestone	0	6
7.	Marl	0	2
8.	Limestone	1	3
9.	Marls with Oysters, &c.	2	6
10.	Limestone, shelly oolitic and cream-coloured 'Roof' of Slate	1	8
11.	Stonesfield Slate, 'Top hard,' compact, grey crystalline	5 in. to 0	7
12.	Soft fissile Sandstone 'Pendle'	9 in. to 1	0
13.	Limestone, coarsely fissile and oolitic, with clay inclusions, concretions, black carbonaceous markings and fragments of *Rhynchonella* and *Trigonia impressa*	2	0
14.	Marl, brown fissile and sandy	0	3
15.	Shelly Limestone, laminated and banded with clay inclusions in the upper part; fawn coloured with Oysters	2	3
16.	Soft fissile Sandstone with carbonaceous markings	0	5
17.	Limestone, compact, close-grained, fawn-coloured with carbonaceous markings and clay inclusions	7	6
18.	Limestone, close-grained, buff-coloured	5	6
19.	Clay	1	6
20.	Limestone, compact, buff-coloured	2	8
21.	Marl	0	4
22.	Limestone, white, shelly and crystalline, with *Mytilus Sowerbyanus*, *Rhynchonella concinna*, and *Ostrea Sowerbyi*	1	3
23.	Black Clay, crowded with *Placunopsis* in places, with *Perna*, *Nucula*, and *Ostrea*	1	7
24.	Shelly earthy Limestone, made up mainly of Oyster fragments, and passing into a brown, blue-hearted Limestone crowded with shells, *Perna quadrata*, large *Cyprina*, *Corbula*, and *Macrodon*	2	0
25.	Black Clay	0	11
26.	Hard oolitic Freestone, blue-hearted, made up of whitish oolites in blue or brown base	2	0
27.	Rubble	0	3
28.	White fine-grained Limestone with few shells	1	2

Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities. (*Chapelhall Section.*) *Report of the Committee, consisting of* Mr. J. HORNE (*Chairman*), Mr. DAVID ROBERTSON, Mr. T. F. JAMIESON, Mr. JAMES FRASER, Mr. PERCY F. KENDALL, *and* Mr. DUGALD BELL (*Secretary*).

APPENDIX—*On the Chapelhall Clay, by* D. ROBERTSON . . . . Page 313

I. LOCALITY AND PREVIOUS NOTICES.

CHAPELHALL is a little mining village situated in the north-eastern part of Lanarkshire, about twelve miles east from Glasgow and two miles south from Airdrie. Its name has been well known to geologists for more than thirty years past from its being usually mentioned in works relating to the science as the highest locality in Scotland where 'shelly clay' has been found (510 feet above the sea). That of Clava, near Inverness, which the Committee reported upon last year, is of more recent discovery, and has not been so generally referred to.

It may be useful, first, to present a summary of the hitherto existing information regarding this 'deposit.'

(i.) *Mr. Smith, of Jordanhill.*—The 'shelly clay' at Chapelhall was first brought into notice by Mr. Smith, of Jordanhill, in a paper read to the Geological Society in 1850, and republished in his well-known little volume of 'Researches in Newer Pliocene and Post-Tertiary Geology,' in 1862. The following is the passage referring to this 'deposit:'—

'Having been informed by Mr. John Craig, F.G.S., that a bed of shells had been discovered near Airdrie, much higher than any previously found in Scotland, I considered it of importance to ascertain the exact amount of the elevation above the present level of the sea, as well as the species of the shells, and the nature of the deposit in which they are found. Mr. Craig kindly accompanied me to the locality, which is near the Monkland Iron Works, and about fourteen miles to the south-east of Glasgow.

'The shelly deposit in question proved to be a bed of the *Tellina proxima*, Brown (*T. calcarea*? Linn.), an Arctic species extremely abundant in the Clyde Pleistocene beds overlying the till, and which I had formerly procured from a brick-work in the same neighbourhood.[1] The shells in the present instance were discovered by Mr. James Russell, an operative miner, in digging a well.'

Mr. Smith then states that he ascertained the elevation of the place to be, on the surface, 524 feet above the sea, which is 'at least 150 feet higher than the highest level at which any shelly deposits have been hitherto discovered in Scotland.' He continues:

'The most remarkable circumstance attending the present discovery is that the shells were imbedded in the stratified clay below the till.

'Mr. Russell states that at the depth of 14 feet from the surface, after passing through the till, he came to a bed of brick-clay containing the shells, which were therefore 510 feet above the level of the sea. I could entertain no doubt as to the nature of the superincumbent matter, as that part of it which had been thrown out was left lying at the mouth of the well. It was unquestionably the true till. Indeed, if I had entertained any doubt as to this point, it would have been removed by the discovery of a small granite boulder, which was found about 2 feet above the bottom of the till. The nearest granite rock in that direction (N.W.) is at Cruachan, about sixty miles N.W. of Airdrie. . . .

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[1] This refers to shells previously stated to have been found by Mr. Craig near Airdrie, at a height of 350 feet. See *Researches*, &c., p. 17. (The place, an old brickfield, has long been filled up.)

'I may add that Mr. Russell states that after passing through the shelly bed of brick-clay, he came again to the till, thus proving indisputably what has always been suspected, that there has been more than one deposition of the till or boulder-clay.'[1]

(ii.) *Sir Archibald Geikie.*—In the preparation of his valuable memoir on 'The Phenomena of the Glacial Drift of Scotland,' published in 1863,[2] Sir Archibald Geikie visited the spot, also under Mr. Russell's guidance. He described it as situated 'on the crest of a ridge which, rising high above the surrounding country, commands an extensive view across the lower part of the basin of the Clyde. On the water shed of this high-lying ridge a well was sunk some years ago, and while the excavations were in progress the shells were found.' Sir Archibald then gives particulars corresponding with those stated by Mr. Smith, adding that the till underneath the shelly clay was 'about 24 feet thick, and lay directly on the Carboniferous strata of the district. The brick-clay at its thickest part,' he continues, 'measured 2 feet 1 inch in depth, but thinned away rapidly on every side, so as to allow the upper and lower till to come together. From a number of additional wells, sunk on purpose, Mr. Russell ascertained that the clay lay in a hollow of the undermost till, and that this hollow measured about 19 feet long by about 5 feet broad. Pits which were dug beyond the boundary of this little trough showed a great depth of the usual till, but without a trace of brick-clay. The shells consisted entirely, I believe, of *Tellina proxima.* Usually the specimens were broken, but a good many were taken out entire, with both valves together.'[3]

(iii.) *Dr. Crosskey.*—About the same time as Sir A. Geikie's visit, or apparently before it (though the account was later in being published), Dr. Crosskey visited the locality, and made some observations which were communicated in a paper to the Geological Society in January 1865.[4] He remarked: 'One of the most perplexing cases in Scotland, upon any theory of the formation of boulder-clay, has been the alleged occurrence at Chapelhall, near Airdrie, of a bed of clay containing *Tellina calcarea,* intercalated between the masses of true boulder-clay.

'The facts relating to the discovery of these shells have been recorded by Mr. Smith. . . . The present paper will simply examine the question whether the superincumbent matter was, without doubt, the true till.'

After defining what he means by the term 'a compact, unstratified clay, with a large proportion of striated stones, chiefly of local origin,' and stating that 'the glacial shells in the west are never found within the boulder-clay proper,' but 'invariably above it,' Dr. Crosskey proceeds:

'Mr. Russell (the original discoverer of the shells) reports that the shell-clay occupied a kind of basin in the lower till, the section being the following:—

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[1] 'On the Occurrence of Marine Shells in the Stratified Beds below the Till.' *Op. cit.* pp. 139–142.

[2] *Trans. Geol. Soc. Glas.* vol. i. part 2.

[3] *Ibid.* pp. 58–9.

[4] *Quar. Jour. Geol. Soc.* vol. xxi.

	Ft.	in.
'1. Clay (supposed to be true boulder-clay) . . .	14	0
2. Clay, finer, containing smaller stones, with *Tellina calcarea*, *Cyprina Islandica*, and a large *Balanus*, in the deepest part, but gradually thinning out .	2	1
3. Boulder-clay resting on carboniferous beds . .	—	

'With great kindness, Mr. Russell sank a fresh well seven yards from the old one, and the following section was exposed:

	Ft.	in.
'1. Surface soil	1	0
2. Upper clay	5	3
3. Boulder-clay not pierced through	9	6

'There were decided distinctions between the upper and lower clays. . . . The upper clay was looser and more easily worked than the lower. . . . The junction between the two clays was recognised by Mr. Russell as the exact position at which he had found the original shell-bed.'

Dr. Crosskey added:—'There is no evidence whatever that the Chapelhall fossils were *in* the boulder-clay, in any sense which would make that clay a marine formation.'

From the foregoing quotations it is apparent that the references made by Mr. Smith, Sir A. Geikie, and Dr. Crosskey, to the occurrence of shelly clay in the Chapelhall well section, rested solely on the statements of Mr. James Russell.

With the view of obtaining further information the Committee resolved to re-examine the well section and to put down a series of trial bores.

II. Examination by the Committee.

1. *The Well Section.*

Mr. James Russell, the original authority regarding this shelly clay at Chapelhall, died about fourteen years ago. The cottage which he built and occupied, and in the garden of which the 'well' is situated, stands at the west end of Chapelhall, and somewhat higher than the village, near the summit, as has been said, of the ridge on which the village is built. It is called 'Wanlock Cottage,' and is now occupied by Mr. James Lindsay, a mining foreman, who purchased it several years ago from Mr. Russell's son.

Mr. Lindsay, having been informed of the object of the proposed examination by the Committee, kindly agreed to afford every facility for the work and assist it by every means in his power.

An arrangement was accordingly made that the well should be emptied and the stone-work removed, so as to expose the section all round to a depth of at least 15 or 16 feet.

Mr. Robert Dunlop, of Whiterigg, Airdrie, obligingly assisted Mr. Lindsay in the operations, and the Secretary of the Committee repeatedly visited the spot during their progress.

On Saturday, March 24 last, the section being then exposed to a depth of fully 15 feet from the surface, the Chairman, Mr. Horne, met

Mr. Dunlop and the Secretary by appointment at the well, and made a careful examination of the section.[1]

Underneath 2 feet of surface soil they found the materials composed entirely of the typical boulder-clay of the district, full of stones, subangular, and more or less striated, chiefly from the adjacent Coal Measures, with a few red sandstones, conglomerates, and schists from the West Highland border. Two grey sandstone boulders of considerable size appeared on the sides of the well, one on the N.W. side and the other nearly opposite on the S.E. side, at a depth of between 12 and 13 feet from the surface.

No trace of any shelly clay or of shells was found.

Samples of all that could be obtained, viz. the boulder-clay, were taken :—

(1) From a depth of 14 feet to 14 feet 6 inches.
(2) „ 14 feet 6 inches to 14 feet 11 inches.
(3) „ 15 feet to 16 feet.

On Monday, March 26, Mr. Horne, Mr. Bell, and Mr. Dunlop again met at the well, and in their presence the examination was carried down another 2 feet, making the greatest depth reached about 17½ feet from the surface. Samples were then taken :—

(4) From a depth of 16 feet to 17 feet.
(5 and 6) „ 15 feet to 16 feet.

Portions of the whole were despatched to Mr. David Robertson for examination, and also to the office of the Geological Survey in Edinburgh.

Mr. Robertson's report is subjoined.

2. *Boring Operations Around the Well.*

The result of the excavation of the well being so far negative, the Committee deemed it advisable, lest former operations had removed or concealed the shelly clay from the sides of the well, to put down some bores at various points at a short distance around it. For this purpose they employed Mr. James Pollock, whose services had been obtained in their former investigations at Clava. Mr. Pollock was first instructed to put down four bores at various points around the well to a depth of about 17 feet. The position of these bores (Nos. 1 to 4) is shown in the following diagram.

The diameter of the well after the masonry had been removed was 4 feet 9 inches at the surface, and 4 feet 3 inches at a depth of 15 feet.

The distances of the bores from the sides of the well were in each case about 2½ feet.

Owing to a large boulder, No. 4 bore had to be abandoned, and bores 4*a* and 4*b* were put down first westward and then southward from No. 4 (see 'Borer's Journal').

After these bores had been put down and reported on by Mr. Pollock it was suggested that, as a considerable space intervened between bores Nos. 1 and 4, and again between Nos. 3 and 4, it was possible that a bed of clay of some breadth might extend diagonally between these without being touched by them. It was considered advisable, therefore, to put down two other bores in the positions marked (No. 5 and No. 6). These additional bores were also done by Mr. Pollock.

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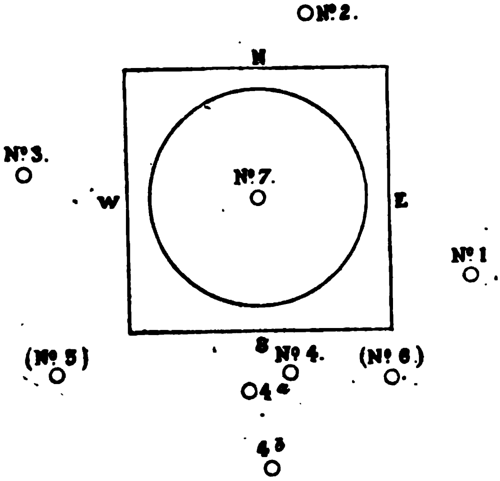
[1] When the operations were in progress, the Chairman and Secretary examined the title-deed conveying the small property from the late Mr. Russell's son to the present owner, Mr. Lindsay, and obtained other evidence of the location of the well.



Finally, another bore, No. 7, was put down from the bottom of the well in order to reach the rock, which Sir A. Geikie had been informed was 24 feet beneath the shelly clay.

When the boring was in progress Mr. Macconochie, of the Geological Survey, at the request of the Chairman, visited the spot to examine the material and report if any change was observable. Mr. Dunlop and the Secretary were also present.

The following is Mr. Pollock's journal of the bores and remarks :—

Journal of Bores at Lindsay's Well, Chapelhall.

—	No. 1 East of Well	No. 2 North of Well	No. 3 West of Well
	Ft.	Ft. in.	Ft.
Surface and ashes . . .	1	1 0	2
Brown sandy clay and stones .	9	9 0	8
Blue clay and stones . .	7	6 10	7
Total	17	16 10	17

—	No. 4 South of Well	No. 4a 1 ft. 8 in. W. of 4	No. 4b 8 ft. S. of 4 and 4a
	Ft. in.	Ft. in.	Ft. in.
Surface and ashes . . .	1 0	1 0	1 6
Brown sandy clay and stones .	7 0	7 0	8 6
Blue clay and stones . .	3 6	2 8	7 0
Total . . .	Stopped by large boulder.		17 0

Journal of Bores at Lindsay's Well, Chapelhall—(continued).

—	No. 5 South-west (between 4 and 3)	No. 6 South-east (between 4 and 1)	No. 7 From bottom of Well	
	Ft.	Ft.	Ft.	in.
Surface and ashes . . .	1	2	17	0
Brown sandy clay and stones .	9	8		
Blue clay and stones . .	7	8	30	10
Total	17	18	Rock not reached	

With regard to Nos. 5 and 6, which were put down to divide the space between the others, and touch any bed that might extend diagonally between them, either to S.W. or S.E., Mr. Pollock wrote: 'I have found no difference in the stuff I went through.' And with reference to No. 7, which was put down in the expectation of touching the rock at 24 feet from the bottom of the well (or 40 feet from the surface), as reported, he wrote: 'I have finished bore in well, and put it down 47 feet and got no rock, and found no difference in clay from top to bottom; it was all blue clay and small free-stones.

'JAMES POLLOCK.

'Plains, April 11, 1894.'

Further, in answer to an inquiry on the point, Mr. Pollock wrote:—

'I don't believe the ground had been disturbed in any way, at any of the places where I put down bores at Chapelhall, because they were all mostly the same—the brown clay on the top, then the blue clay under it. They all seemed to be quite naturally formed, and in no way disturbed. Even the bottom of the well was the same.

'J. P.'

The Committee may here remark that, as is well known, a deposit of boulder-clay is generally browner in colour and looser in texture towards the top, owing to the action of the ordinary weathering agencies upon it, and not to any special change of conditions during its deposition.

Mr. Macconochie reports as follows:—

'I was present at Chapelhall (April 6, 1894) when Mr. Pollock brought up the materials from bores Nos. 1 to 6, from depths exceeding 14 feet. They consisted of the ordinary boulder-clay of the Chapelhall well section.

'A. MACCONOCHIE.'

III. CONCLUSION.

As the result of their investigations, the Committee beg to state that they have found no evidence in proof of the occurrence of shelly clay at Chapelhall either in the original well section or in the trial bores.

The Committee recommend that they should be reappointed with a grant to investigate the shelly clays at Tangy Glen, near Campbeltown, and on the Lag and Rosie in Arran.

APPENDIX.

Report on the Chapelhall Clay. By Mr. David Robertson, *F.G.S.*

Millport, May 5, 1894.

The samples of clay that were submitted to me for examination from Chapelhall from depths of 14 to 17 feet were, as taken from the pit, of a dark slatish colour, and when dry of a light grey colour. The mud referred to in the following list is that portion of the clay that passed through a sieve of 96 meshes to the inch, and the sand is what passed through a sieve of 24 meshes to the inch, and the stones are those retained in the same sieve. That which is commonly called 'floats' is that which rises to the surface of the water when the clay is dissolved, after having been dried. The dissolved clay, when stirred up, retained its dark colour, but after standing a little a reddish brown formed on the surface.

The 'floats' are not referred to in the subjoined list, as they were all alike in being quite barren of animal remains, and almost of everything else.

From the Well.—No. 1. *Depth,* 14 *ft. to* 14 *ft.* 6 *in.*

Mud	50 per cent.
Sand	10 „
Stones	38 „

The sand consists of white and black grains, the white preponderating greatly, or, I may say, with a small mixture of black grains, both apparently rough or angular.

The stones mostly water worn, a few portions angular. Few striations were noticed. This may be accounted for as few of the stones are such as would readily take and retain the markings.

No. 2. *Depth,* 14 *ft.* 6 *in. to* 14 *ft.* 11 *in.*

Mud	62 per cent.
Sand	12 „
Stones	26 „

The sand consists of white and black grains, mostly white, both angular.

The stones more or less water worn, but not to any great extent. Many pieces were angular, some appear to have been crushed. No striations were noticed.

No. 3. *Depth,* 15 *ft. to* 16 *ft.*

Mud	50 per cent.
Sand	18 „
Stones	30 „

The sand light grey composition as above.

Stones much the same as No. 2.

No. 4. *Depth,* 16 *ft. to* 17 *ft.*

Mud	60 per cent.
Sand	14 „
Stones	25 „

The sand consists of white and black grains, chiefly white.

Stones mostly water worn. The pieces of shale generally more or less striated, or indented, or both, and a few bits of coal, some with marks of abrasion. Also bits of vitrified stone. These show no marks of rubbing or of having been much rolled about. In this sample a small fragment of a valve of a bivalve shell imbedded in a piece of Carboniferous shale.

No. 5. *Depth,* 15 *ft. to* 16 *ft.*

Mud	60 per cent.
Sand	14 ,,
Stones	25½ ,,

The sand consists of white and black grains, the white prevailing greatly.

Stones mostly water worn, the lesser portion more or less angular. Most of the bits of shale are striated or indented. The coal here has traces of water action.

No. 6. *Depth,* 15 *ft. to* 16 *ft.*

Mud	60 per cent.
Sand	14 ,,
Stones	25 ,,

The sand light grey.

Stones mostly water worn. Many pieces of coal and small pieces of slag.

From the Bores.—Bore No. 1. *Depth,* 14 *ft. to* 17 *ft.*

Mud	59½ per cent.
Sand	13½ ,,
Stones	6 ,,

The sand light grey.

Stones mostly water worn. Many small pieces of coal, some abraded, and three small bits of slag.

Bores Nos. 2 *&* 3. *Depth,* 14 *ft. to* 17 *ft.*

Mud	38½ per cent.
Sand	16½ ,,
Stones	44 ,,

Sand light grey.

Stones mostly water worn, only one piece noticed striated. A few pieces of coal, some with marks of rubbing. Some bits of slag.

Bore No. 4. *Depth,* 14 *ft. to* 17 *ft.*

Mud	66 per cent.
Sand	17 ,,
Stones	17 ,,

The sand light grey.

In this bore the stones are all small, and from the absence of larger and heavier ones the proportion of mud is more and that of the stones less. No striation was noticed. Coal and small bits of slag were present.

As stated above, the floats were not taken into account, as they were all alike in being quite barren of animal remains and almost of everything else, which is a very different condition of things from the abundance of float that we generally find in the post-Tertiary shell-bearing clays. The samples of sand are of a very uniform colour, and any little variation that appears may have been caused by the black grains being lighter and coming more to the surface than the white in one case than another.

From the abrasions on the above samples of coal, there can be little doubt that it belonged to the deposit.

As no rubbing is noticed on any of the pieces of slag, and the fractured edges appearing sharp, it is most likely that it got into the clay accidentally. At the same time it is curious that it is met with in so many of the samples both of the pits and bores.

So far as I can judge from the samples of the clay and the average proportion of stones and mud, also the paucity of the floatings, and the entire absence of animal remains (with the exception of a small fragment of shell embedded in a piece of Carboniferous shale), I have no doubt whatever that the deposit is characteristic boulder-clay.

The Volcanic Phenomena of Vesuvius and its Neighbourhood.—Report of the Committee, consisting of Mr. H. BAUERMAN, Mr. F. W. RUDLER, Mr. J. J. H. TEALL, *and* Professor H. J. JOHNSTON-LAVIS. (*Drawn up by* Professor H. J. JOHNSTON-LAVIS.)

Vesuvius.—Since the last report lava has continued to pour forth from the top of the new lava-cone in the Atrio del Cavallo, sometimes in small quantities, at others in considerable abundance. On no occasion, however, did the lava issue beyond the limits that it had reached in the years 1891–92. In fact, the whole of that eastern part of the Atrio known as the Val d'Inferno has not been invaded at all by the new lava during or since its issue in the spring of 1891. The consequence of this has been that it has continued to pile itself up around the line of fissure by which it issued, and still further add to the dimensions of the great lava-cone that it had built up in the Atrio. So great has this cone become that it constitutes a prominent feature in the outline of the volcano as seen from Naples. The eminence of Somma is separated from Vesuvius by the depression of the Atrio. This notch, so to speak, in the general outline was terminated below by an almost horizontal line, which is now replaced by an obtuse cone, so that many people speak of three summits to the Vesuvian volcano. This is rather an exaggeration, for although the new lava-cone is of very considerable dimensions, for the time occupied in its growth, yet it cannot compare with that of the cone of Vesuvius on one side or the ridge of Somma on the other.

The whole of this new cone is entirely built up of lava, by far the greater part being of the *pahoehoe* or corded type; only now and then during marked activity has there been produced any lava with a rugged scoriaceous surface. The occasion was therefore a very valuable one to determine the slope of such a lava-cone. This was done only normally to the line of fissure by which the lava issued, and which makes the cone terminate in an elongated ridge rather than in a point. Practically all these clinometric observations, which were taken with great care, gave angles varying from 13° to 15°.

Comparing this angle with that of such mountains as Etna or Mauna Loa, we must consider that both are composite cones, have experienced many disturbing influences such as the formation of parasitic eruptive outlets from which lava streams have issued far away from the summit, and have thus diminished the general slope of the volcano. Those mountains are usually considered to have an average slope of 10°. The Hawaiian lavas are, as is well known, exceptionally fluid, and we could hardly expect cones of greater slope than 10°. At Etna the lavas have always been more viscous from their lower temperature and the compound or false viscosity given to them by the large number of porphyritic crystals already existing in the magma at the time of emission, just as earth mixed with water may produce a viscous mud. These new lavas of Vesuvius, as is the case with all those that issue high up on the volcano and in small quantities, were very viscous owing to their low temperature and advanced crystallisation, so that soon after the material poured out it was prevented from flowing by slight further cooling. We may take therefore this average slope of 14° as the best and most correct estimate for a lava of this nature.

This recent outflow exhibits most of the varieties of surface to be met with in the type of lava above mentioned, such as corded shapes of different kinds, irregular globular surfaces, sheets, and plates either in position or reared on end, and tunnels of every variety, frequently with continuations as walled canals, of which a good example is seen in the photograph exhibited. A magnificent lava hump is to be seen in another photograph, and was formed right under the escarpment of Somma. The origin of these humps is still obscure. They are common on most large flows of corded lava of Vesuvius, but unfortunately I have never been present at their formation, nor do I know of anyone who has.

The points of issue of the lava occurred at various spots along a line corresponding with the strike of the radial dyke to which it owes its origin, so that the new lava has as a summit an irregular ridge running nearly north and south. Of course the actual highest point is nearly always that where the last lava issued. Generally more than one spot along this line gave out lava at the same time. The fluid rock flowed sometimes on one side, sometimes on the other, so that the general public at Naples were only from time to time treated to a glimpse of Nature's fireworks, and when the lava flowed in the opposite direction it was often announced that it had altogether stopped.

During the last year several new conical spiracles were formed, but none of them comparable in perfection of form to those described in the last two reports, or exhibiting equally interesting features.

No very interesting minerals were produced as sublimates. In fact, only two species are worthy of mention. On one occasion a small quantity of tenorite was formed in one of the spiracles. Soon after the lava had entirely stopped flowing in February, sublimates of potash-bearing halite were very abundant around about the vents, in beautiful fern-like skeletons, in which a number of feathery branches radiated at right angles from a stem representing usually about three edges of a cube, and were themselves so many edges of smaller cubes. Sometimes this halite was grey, from minute hæmatite crystals being deposited with the salt, which likewise was in some cases greenish from copper impurities. Most, however, was of a beautiful snow white. One small cave in particular, about the size of a man's body, was clothed with the most glistening white lining, and from the roof and walls showers of crystals fell from time to time. These were not visibly red-hot in bright diffused daylight, but looking towards the shaded inner extremity of the cavity a bright red incandescence was visible.

In a short time, with suitable apparatus, I collected over two kilogrammes of this material absolutely free from mechanical impurities.

Along many of the cracks of the lava beautiful glassy crusts of halite, more or less impure, were formed, and often showed a dull red heat in daylight. These crusts on being removed become rapidly opaque and milky in hue, and audibly cracked into starch-like columns, due to the rapid contraction on cooling—producing, in fact, a miniature basaltic structure.

About February 5, 1894, the lava was issuing in very small quantity, and by the 7th showed no trace of movement. Yet even in May cracks in the lava near its point of exit were incandescent some distance in, and the saline incrustations mentioned above were in full perfection.

Coincident with the arrest of the lateral outflow, the lava rose in the chimney and the red reflection from the top of Vesuvius that had been absent for so long, with rare exceptions, was again almost daily visible. The level of the lava in the main chimney soon rose to the bottom of the new crater that had been forming, and increasing in size during the time the lateral issue of lava had been going on, and commenced the filling up of that cavity by the formation of a cone of eruption, so that almost coincident with the arrest of the leakage of lava laterally the central activity changed from the crater- and dust-forming stage to the lava cake- and cone-forming stage.

I made a careful examination of the summit of Vesuvius about the middle of May. The crater in an east and west direction was about 150m. in diameter, and its depth, then decreasing, was about the same. The walls were remarkably steep, in some places even vertical or overhanging. The bottom could be seen with difficulty owing to the crumbling nature of the edges. The walls are nearly all covered by sublimates or dust that has adhered and crusted them over, so that several dykes both solid and hollow can no longer be distinguished. This is especially the case with the one formed during the 1891 outburst. The details of the great rift of the 1880–81 and subsequent eruptions on the east side of the great cone were still easily discernible. On the south side, and a little to the east, a wall of rock stands out from the side of the crater and is directed nearly towards the centre. It is capped by a pinnacle of rock, and is really the old dyke of the 1885 eruption.

Just to the east of that wall, and partly owing to its existence, the slope of the inside of the crater is less in that direction. Here the guides had made a little path for a few metres down. On examining carefully the condition of things from its lower termination, which so far aided little the view of what was going on at the crater-bottom, I found that by extending it down a slope, and then cutting a ledge farther round to the east at a suitable point, a bracket-like platform some metres square could be reached, which is about half-way down the crater. Later the path was further widened by me and made more commodious, and now gives easy access to the platform from which one can look right into the vent of the volcano and watch with ease the boiling up of the lava and the ejection of the great blobs and cakes that are rapidly filling up the crater. Unfortunately, owing to the well-like shape of the crater, the shadows due to the vapour column spreading out overhead, and the dark colour of the rocks, instantaneous photography could not be utilised to record this interesting and ever-changing scene.

As is usual at some period after an eruption, feathery gypsum is a common product in the cavities of the old scoriæ, and is associated at the fumaroles with a little sulphur (an exceedingly rare mineral at Vesuvius) with abundance of molysite and kremersite.

In the Campi Phlegræi little of novelty has come to light. A tunnel and a deep shaft which is being constructed in Naples to complete the drainage works have brought several interesting sections to light, but not of sufficient completeness to be yet worth recording.

The Marine Zoology of the Irish Sea.—Second Report of the Committee, consisting of Professor A. C. HADDON, Professor G. B. HOWES, Mr. W. E. HOYLE, Mr. I. C. THOMPSON, Mr. A. O. WALKER, *and* Professor W. A. HERDMAN (*Chairman and Reporter*).

[PLATE I.]

THE work has chiefly been carried out by the three last-named members of the Committee along with their colleagues of the Liverpool Marine Biology Committee and other naturalists who have been working at the Port Erin Biological Station during the year. The present report is drawn up by the Chairman, with contributions from the various specialists mentioned below in connection with the several groups of animals. The extensive lists and notes received from Mr. Walker and Mr. Thompson should be specially acknowledged.

The limits and more prominent physical features of the region of the Irish Sea which this Committee was appointed to explore were sufficiently described in last year's report, and may be readily seen from the accompanying chart (Plate I.), which is a modification, with some additions, of the chart given in the former report.

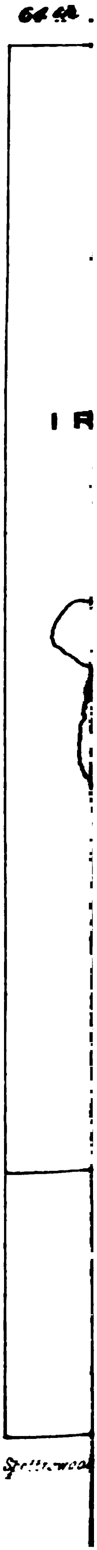
The work this year, in addition to the further exploration of the district by dredging, trawling, and tow-netting, for the purpose of adding to the records of the fauna, has consisted largely of the determination of the submarine deposits spread over the floor of the Irish Sea—their nature, probable origin, relation to depth, and effect upon the distribution of the fauna. The reasons for undertaking this extension of the work were—

1. There can be no doubt that the nature of the bottom has a profound influence upon the assemblage of animals at a particular spot, and limits, perhaps, as much as any other factor the distribution of non-pelagic species in the sea.

2. That being so, it becomes of importance to determine, if possible, why there is a particular deposit at a special spot, and how much connection there is between the geological formations of a shore and the submarine deposits lying off that coast.

3. Some of the deposits described in our last report proved of such interest to the geologists at the Nottingham meeting that the Committee of Section C supported the application for the reappointment of this committee on the grounds that a collection of typical deposits from the floor of the Irish Sea would be of geological interest. Sir Archibald Geikie asked that such a series should be formed and sent to the Jermyn Street Museum ; so on all the expeditions during this year sample bags of the deposits met with have been preserved, and, after examination, have been sent up to the Geological Survey. These deposits will be discussed in a later part of the report.

The object of the Committee, then, has been, not merely to collect animals, but to investigate the condition of the sea-bottom in the various parts of the area, and correlate, if possible, the fauna with the environment.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THE DREDGING EXPEDITIONS.

The Committee have organised the following expeditions since the last report :—

I. August 22.—The Committee hired the steam trawler 'Albatross' for dredging from Port Erin to the south and west, round the Calf Island, as follows :

1. Off Halfway Rock and Bay Fine, half a mile from shore, 15 fathoms; bottom small gravel and broken shells. Conspicuous animals :[1] *Antennularia ramosa*, *Sertularia abietina*, *Aglaophenia myriophyllum*, *Cellaria fistulosa*, *Sarcodictyon catenatum*, *Porania pulvillus*, *Galathea intermedia* (with the Bopyrian parasite *Pleurocrypta intermedia*), *Ascidia plebeia*, *A. mentula*, *Cynthia morus*.

2. From off Kitterland to Halfway Rock, half a mile off, 17 fathoms ; bottom stones and large shells, with *Cliona celata* (massive form), *Ophiopholis aculeata*, *Ascidia venosa*, *Cynthia morus*.

3. North of Kitterland, three-quarters of a mile off, 18 fathoms ; bottom small gravel and shell sand, with *Sarcodictyon catenatum*, *Lepralia edax*, *Cellepora pumicosa*, *Echinocyamus pusillus*, *Ophiocoma nigra*, *Xantho tuberculatus*, *Inachus dorsettensis*, *Ebalia Cranchii*, *Ascidia mentula*, *A. plebeia*, *Perophora Listeri*, *Capulus hungaricus*, *Murex erinaceus*.

4. Off the north-west corner of Calf Island, a quarter mile off, 17 fathoms ; bottom stones ; very many *Ophiocoma nigra*, with *Stichaster roseus*, *Ophiothrix fragilis*, *Ocnus brunneus*, *Lineus longissimus*, *Cynthia morus*.

5. South end of Calf Sound, half a mile off, 15 fathoms ; rough hard ground, probably rock *in situ*. Several large stones came up, covered with *Sertularia abietina*, encrusting polyzoa, and *Ciona intestinalis*.

6. North-west of Calf Island, half a mile off, 18 fathoms ; bottom stones with many *Ophiocoma nigra*, with *Sycandra ciliata* (large), *Chætopterus* sp., *Ophiopholis aculeata*, *Solaster papposus*, *Thyone fusus*, *Ascidiella scabra*, and *Ciona intestinalis*.

7. North-west of Calf Island, further out, 20 fathoms, bottom stones, shells, and echinoderm spines, with *Sarcodictyon catenatum*, *Aglaophenia tubulipora*, *Spatangus purpureus*, *Aphrodite aculeata*, *Pectunculus glycimeris*, *Ciona intestinalis*, and *Perophora Listeri*.

8. From off Kitterland to across Port Erin Bay, 2 miles off, 18 fathoms ; bottom large shells, with *Perophora Listeri*, *Ascidia mentula*.

9. West of Port Erin Breakwater, a mile out, 17 fathoms ; gravel and rotten algæ, with *Lyonsia norvegica* (alive).

II. On September 11 some of the Committee dredged from a large rowing boat between Port Erin and the Calf Island ; half a dozen hauls were taken about Aldrick and Bay Fine, half to a mile off shore ; depth 15 to 18 fathoms. The hauls overlapped, so all may be considered one locality. Amongst the animals obtained were : *Folliculina ampulla* (in quantity, alive), *Astrorhiza limicola*, *Antennularia ramosa* and other hydroids, *Sarcodictyon catenatum*, *Antedon rosacea*, *Amphiporus pulcher*, *Terebella nebulosa*, *Halsydna gelatinosa*, *Conilera cylindracea*, *Anthura*

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[1] The few species picked out for mention in each haul are not to be regarded as the rarest forms observed. In some cases they are the commonest. They are the forms which at the time seemed to us the most conspicuous and characteristic of the haul—the most noteworthy inhabitants of that ground.

gracilis (new to the district), *Eurynome aspera*, *Galathea nexa* (with Bopyrian parasite *Pleurocrypta nexa*, n. sp., Stebbing), *Doto fragilis*, *Velutina lævigata*, *Ostrea edulis*, *Ascidia plebeia*, *Ascidiella venosa*, *A. virginea*, *Cynthia morus*, *Polycarpa pomaria*, *Corella parallelogramma*, and *Syngnathus acus*.

III. March 20–25.—At Easter the Committee spent some days in shore-collecting at the southern end of the Isle of Man, and hired the steam trawler 'Lady Loch' for two days' dredging. On the first day the floor of the sea to the north of Port Erin from Fleshwick to Contrary Head at Peel was worked at twelve stations within four miles of the coast, and at depths from 10 to 20 fathoms. On the second day nine stations off the west of the Calf Island at depths of from 20 to 25 fathoms were dredged.

March 24.—1. West of Fleshwick Bay, a quarter mile off shore, 13 fathoms; bottom fine sand and broken shells, with *Cliona celata*, *Gemellaria loricata*, *Canda reptans*, *Ophiura ciliaris*, *Galathea intermedia*, *Portunus arcuatus*, *Aporrhais pes-pelicani*, *Trochus magus*, *Ascidia virginea*.

2. West of Fleshwick, further north, half mile off shore, 15 fathoms, bottom small gravel and shells, with *Cycloporus papillosa*, *Hyas coarctatus*, *Macropodia longirostris*, *Venus fasciata*, *Lissocardium norvegicum*.

3. West of Fleshwick, further north, half a mile off shore, 15 fathoms; bottom large shells, a little gravel, with *Pecten tigrinus*, *Venus casina*, many common crabs.

4. One mile north of Fleshwick, half mile off shore, 14 fathoms; bottom much fine gravel, with *Pecten maximus*, *Trochus magus*, *Antedon rosacea*.

5. Off the Cronk, a mile off shore, 14 fathoms; bottom small gravel and some *Melobesia*, with *Tellina crassa* (alive), *Thracia prætenuis*.

6. One mile further north, a mile off shore, 10 fathoms; bottom Nullipores (*Melobesia* and *Lithothamnion*), with compound ascidians.

7. West from South Barrule, a mile off shore, 12 fathoms; bottom Nullipores, with *Antedon rosacea*.

8. Off Niarbyl Point, a mile out (several hauls), 12 fathoms; rough hard ground, with *Antedon rosacea*, *Echinocardium flavescens*.

9. Off Glen Meay, 4 miles out, 20 fathoms; bottom 'reamy' (sand and mud), with *Ophiopholis aculeata*, *Porania pulvillus*.

10. Off Glen Meay, half a mile further north, 21 fathoms; with many *Pecten opercularis*, *Cucumaria Hyndmani*, *Ebalia tuberosa*, *Cellaria fistulosa*, *Scalpellum vulgare*.

11. West of Contrary Head, 4 miles off, 18 fathoms; bottom Melobesia and stones, with *Eugyra glutinans*.

12. West of Contrary Head, one and a half mile off, 13 fathoms; bottom muddy sand with some stones and many ophiuroids, with *Cliona celata* (massive form), *Astarte sulcata*, *Pecten maximus*.

IV. March 25.—1. Off Aldrick (south of Port Erin), a mile out, 18 fathoms; bottom dead shells, shell sand, and echinoderm spines, with *Spatangus purpureus*, *Echinocyamus pusillus*, *Porania pulvillus*, *Henricia sanguinolenta*, *Murex erinaceus*, *Xantho tuberculatus*.

2. Off Kitterland, 1½ mile out, 18 fathoms; bottom dead shells with *Ascidia mentula*, *Cynthia morus*.

3. North-west of Calf Sound, 2 to 3 miles off; 19 fathoms, bottom sand and shells, with *Palmipes placenta*, *Luidia ciliaris*, *Stichaster roseus*,

Thyone fusus and *T. raphanus*, *Cellaria fistulosa*, *Ascidia plebeia*, *Polycarpa comata*.

4. North-west of Calf Island, 3 miles off, 20 fathoms; bottom sand and shell fragments, with *Pectunculus glycimeris*, *Modiola modiolus*, *Pecten maximus*.

5. North-west of Burrow Rock, 3 to 4 miles off, 22 fathoms; bottom shells, with *Pectunculus glycimeris*, *Lissocardium norvegicum*, *Pecten maximus*.

6. North-west of Chicken Rock, 5 miles off, 25 fathoms; bottom dead shells and some sand, with *Sarcodictyon catenatum*, *Chætopterus* sp., *Ebalia tuberosa*, *Ascidia plebeia*.

7. One-and-a-half mile off Bradda Head, 18 fathoms; bottom large shells and broken fragments, with *Asterias rubens* (very large [1]), *Porania pulvillus*, *Ciona intestinalis*.

8. Two to three miles N.W. of Bradda Head, 21 fathoms; bottom muddy sand, with many ophiuroids, *Cucumaria Hyndmani*.

9. Four miles N.W. of Bradda Head, 23-25 fathoms (several hauls); bottom sandy mud, many ophiuroids.

V. May 27.—The Committee hired the steam trawler 'Lady Loch,' and dredged the following localities:—

1. South-east of Calf Sound, a mile from Kitterland, 20 fathoms; bottom subangular gravel (? glacial material), many ophiuroids and *Buccinum undatum*, a few large shells, *Mytilus edulis*, and *Venus casina*.

2. South-east of Calf Sound, half a mile further out, 19 fathoms; some coarse sand and broken shells with the subangular gravel (stones much encrusted) *Spatangus purpureus*, many encrusting polyzoa, *Venus*, *Trochus*, *Pecten*, *Serpula*, *Echinus*, and *Lithothamnion* fragments.

3. South-east of Calf Sound, further on, 2 miles from Kitterland, 20 fathoms; bottom white, shelly (calcareous) sand, mainly organic, lamellibranch and gastropod shells, echinoderm spines and plates, *Cellaria fistulosa* and *Cellepora pumicosa*.

4. South-east of Spanish Head, 2½ miles off, 20 fathoms; bottom sand and broken shells; a few small stones—Triassic sandstone, slate, and pebble of felsite.

5. South-east of Spanish Head, 3 miles off, 22 fathoms; bottom more shelly (fragments large), and a few small pieces of slaty rocks.

6. Off the Chasms, half a mile out, 17 fathoms; bottom muddy sand with much *Lithothamnion* and *Melobesia*, a few shells and small stones, small subangular fragments of slate, grit, Carboniferous limestone (with *Productus*), and pebbles of coarse sandstone.

7. Off the Chasms, a mile out, 19 fathoms; bottom mud and small gravel (small subangular grit and granite), *Amphidotus* and *Echinus* remains, and some shells.

8. Off the Chasms, 2 miles out, 21 fathoms; mixed bottom, sandy mud, small subangular stones and shell fragments.

9. South-east of the Old Mines, near Perwick Bay, quarter mile to a mile off shore, 15 to 18 fathoms (two hauls); bottom Nullipore and gravel (angular grit, slate, vein-quartz); a few shell fragments.

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[1] The specimens we dredge are very much larger than those we find on the rocks of the neighbouring shore. Are there two varieties in the species, a smaller shore and a larger deep-water form, or do the individuals move outwards from the shore as they grow older?

10. Off mouth of Perwick Bay, half a mile off, 12 fathoms; bottom small gravel.

VI. July 8.—The Committee had the use of the Lancashire Sea Fisheries steamer 'John Fell,' and dredged at the following localities :—

1. West of Dalby, 5 miles out, 30 fathoms ; bottom mud, with *Antennularia ramosa*, *Ophiura ciliaris* and *O. albida*, *Pecten opercularis* and *P. pusio*, *Turritella terebra*, *Hyas coarctatus*, *Ascidia virginea*, and *Eugyra glutinans.*

2. Six-and-a-half miles west of Contrary Head (Peel), 38 fathoms; bottom fine mud, with *Brissopsis lyrifera*, *Lipobranchius Jeffreysii.*

3. Seven-and-a-half miles west of Niarbyl Point, 45 fathoms ; bottom fine mud, with *Calocaris Macandreæ*, *Gonoplax rhomboides*, *Panthalis Oerstedi.*

4. Five-and-a-half miles west of Glen Meay, 34 fathoms ; bottom mud, many *Turritella terebra* with *Sagartia Herdmani.*

5. Four-and-a-half miles west of the Cronk, 22 fathoms; bottom broken shells and small stones, with many ophiuroids, *Ebalia tuberosa*, *Eurynome aspera*, *Atelecyclus septemdentatus*, many encrusting polyzoa (twelve species identified), including *Ascopodaria nodosa*, hydroids (fifteen species identified), including *Dicoryne conferta*, new to the district ; also the cumacean *Campylaspis macrophthalma*, Sars, new to Britain.

It may be of some use to place on record the course of procedure at each dredging station on these expeditions. The plan for the day is arranged with the captain of the steamer, and when the first locality is reached the spot is determined on the chart, and the depth verified by casting the lead. Then the dredge (measuring 2 feet 6 inches by 1 foot, and weighing from 30 to 40 lbs.) is sent down with a tow-net tied on to the line about two fathoms from the dredge. Very often a smaller dredge with a bag of cheese-cloth is sent over on the other side of the ship. One or more surface tow-nets are also put out. The tow-nets, both surface and deep, are looked after by Mr. I. C. Thompson, who, after hauling them, first turns out their contents into a clear glass jar of sea-water, and then, after noting the general character of the catch and any specially conspicuous forms, strains off the water through a small bag made of very fine miller's silk, and then transfers the 'plankton' left adhering to the silk into a tube containing a special preservative fluid formed chiefly of spirit, glycerine, and water.

When the dredge is brought up it is emptied on deck, and after a note of the general character of the deposit and assemblage of animals has been taken, any specially large or rare specimens are picked out and transferred to buckets or jars of sea-water or to store-bottles of spirit. Then the heap is spread out so as to form a layer not more than one or two inches in depth, and one or two members of the Committee (Professor Herdman and another) now settle down beside it to pass the entire mass in review inch by inch, working it across a small space of bare deck and turning over every shell, stone, and specimen with an iron spoon, so as to ensure that nothing escapes observation and due record in the note-book. In the meantime the contents of the bottom tow-net have been dealt with by Mr. Thompson, and the apparatus has been lowered for a second haul, or the vessel is steaming on to a new locality. Then Professor Herdman selects a fair sample of the deposit for preservation (for the Geological Survey) in a small canvas bag (10 × 5 inches), care being taken to include some of the characteristic bottom animals—shells, ophiuroids, polyzoa, &c. After this sample has been removed and any special animals required have been picked out and put into store bottles, the whole of the remainder of the haul is passed gradually through our set of three sieves (meshes ¾ inch, ¼ inch, and ⅛ inch respectively), which work up and down in a tall iron cylinder filled with sea-water. The sieves are disconnected and examined at intervals, and in this way many of the smaller animals of all groups are detected and picked out. Finally, the water in which the sieves have been plunging is all strained by Mr. Thompson through his fine silk net, and in this way many of the rarer bottom Copepoda are obtained, while the finer sandy and muddy deposits retained by the finest sieve or in the bottom of the cylinder are packed in canvas bags by Mr. Alfred Leicester for further examination at home. These contain, of course, many minute Mollusca, Ostracoda, and Foraminifera. By the time all these processes have been completed the dredge has usually been hauled again, and a fresh heap is lying on the deck awaiting investigation. On a successful trip the members of the party, on an average four to six in number, are kept constantly occupied, each man at his own work, from the commencement of the first haul till the steamer is turned homewards, and after that the packing and labelling of specimens fill up the time until land is reached.

ADDITIONS TO THE FAUNA.

As most of the expeditions took place round the Isle of Man the material was generally brought back to the Port Erin Biological Station, and sorted out into groups in the laboratory there, and then sent to the specialists. Taking the groups in zoological order the most notable additions as the result of this year's work have been—

SPONGES.—Dr. R. Hanitsch reports that the only actual addition to our sponge fauna made during the last few months is *Leiosella* (*Spongionella*) *pulchella*, Sowerby, which was dredged on May 14, 1894, at 14 miles N. by W. from the Liverpool N.W. Lightship. This species was previously known from the coast of Durham, the Skerries, Shetland, the west coast of Ireland, the east coast of Greenland, and the North Pacific. A few other doubtful species await further investigation.

We are indebted for a list of the HYDROID ZOOPHYTES and POLYZOA which we have collected to Miss L. R. Thornely, who has proved that the *Lafoëa pigmæa* of Alder possesses an operculum, and therefore belongs to the genus *Calycella*, and also has Gonothecæ which were previously unknown. The total number of species of hydroids in our area is now eighty-nine, and the last dredging expedition has given us an interesting addition to our fauna in *Dicoryne conferta*, which was growing on an *Aporrhais* shell; it was only known previously from Cullercoats, Orkney, and Shetland. Of polyzoa 123 species and fourteen varieties have now been recorded. The most recent find is *Crisia ramosa*, which was recently described by Harmer from Plymouth, and which we find also at Port Erin.

Mr. E. T. Browne has, during some visits to Port Erin, paid special attention to the MEDUSÆ, and has kindly supplied us with a list of a dozen species, one of which, *Amphicodon fritillaria*, has not previously been recorded for British seas. He has also found on several occasions a Siphonophore (probably *Halistemma*) in Port Erin Bay and *Lesueuria vitrea*, both new to our district, and the *Halistemma*, probably an addition to the British fauna.

Amongst WORMS new to the record are the turbellaria *Fecampia* (the pear-shaped white cocoons of this form are not uncommon on stones in pools at Port Erin), and *Stylocoplana maculata* (identified by Mr. Gamble), and the annelid *Gattiola spectabilis* (Johnston) collected at Port Erin by Mr. Beaumont.

Professor G. S. Brady has kindly examined two gatherings of OSTRACODA from dredged material, and reports the following species:— I. Off the Calf Island, 20 fathoms:

Pontocypris trigonella, G. O. Sars; *P. mytiloides*, Norman; *Bairdia inflata*, Norman; *Cythere Jonesii*, Baird; *C. emaciata*, G. S. Brady; *Loxoconcha tamarindus*, Jones; *Cytherura cornuta*, G. S. Brady; *C. striata*, G. O. Sars; *C. sella*, G. O. Sars; *Pseudocythere caudata*, G. O. Sars; *Cytheropteron latissimum*, Norman; *Sclerochilus contortus*, Norman; *Paradoxostoma ensiforme*, G. S. Brady; and *Philomedes interpuncta*, Baird.

II. Off Contrary Head, 40 fathoms, the following were found:— *Cythere tuberculata*, G. O. Sars; *C. emaciata*, G. S. Brady; *C. Dunelmensis*, Norman; *C. antiquata*, Baird; *C. Jonesii*, Baird; *Krithe Bartonensis*, Jones; *Loxoconcha impressa*, Baird; *L. guttata*, Norman; *Cytheropteron latissimum*, Norman; *C. alatum*, G. O. Sars; *Cytheridea papillosa*, Bosquet; *Bythocythere acuta*, Norman; *B. turgida*, G. O. Sars; *Machærina tenuissima*, Norman.

In regard to the COPEPODA, Mr. I. C. Thompson has drawn up a general report upon the additions to our knowledge of the group (see p. 325); while Mr. Andrew Scott, 'fisheries' assistant to Professor Herdman, has supplied the following notes upon some new species of *Ectinosoma* and other Copepoda, at which he has been specially working:—

'*Longipedia minor* (T. and A. Scott).—A few specimens of this species were collected by hand-net in the rock-pools at Hilbre Island in March. It is easily distinguished from *L. coronata* (Claus) by its much smaller size.

'*Ectinosoma Normani*, n. sp. (T. and A. Scott).—Several specimens of this *Ectinosoma* were obtained in material from Barrow Channel collected by Professor Herdman in May. When fresh this species has a brilliant red spot on the lower angles of the cephalothorax, and in this respect it agrees with *E. erythrops*, Brady.

'*Ectinosoma Herdmani*, n. sp. (T. and A. Scott).—This species was found in considerable numbers in the stomachs of young dabs (*Pleuronectes limanda*) sent to the fisheries laboratory from Blackpool, as many as sixteen specimens being obtained from a single stomach. We have also obtained specimens of this new species from the Firth of Forth.

'*Ectinosoma gracile*, n. sp. (T. and A. Scott).—One or two specimens of this species were obtained among dredged material collected at Port Erin by Professor Herdman, Easter, 1894.

'*Ectinosoma pygmæum*, n. sp. (T. and A. Scott).—This species was obtained from the same material as the last, and is the smallest *Ectinosoma* known to us: it measures only $\frac{1}{76}$th of an inch (·33 mm.).

'*Bradya minor*, n. sp. (T. and A. Scott).[1]—A few specimens of this new *Bradya* were obtained in rock-pools at Hilbre Island, along with *Longipedia minor*.

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[1] The above species of *Ectinosoma* and *Bradya* are figured and described in a revision of the British species of Copepoda belonging to the two genera *Ectinosoma* and *Bradya*, by T. and A. Scott, which is to be published at an early date.

'*Dactylopus rostratus* (T. Scott).—A single specimen was obtained among some dredged material collected at Port Erin by Professor Herdman, Easter, 1894.

'*Pseudanthessius Sauvagei* (Canu).—A few specimens were obtained by washing a number of *Spatangus purpureus* which were trawled in the central area, 21 miles W.N.W. from Morecambe Bay Lightship, on April 3. This rare species was only added to the British fauna last year, when it was found in the Firth of Forth, and the present is the second time it has been observed in the British area.'

Mr. Thompson reports as follows :—

'Eleven species of Copepoda new to the district have been recorded during the past year, viz., *Cyclops magnoctavus*, Cragin ; *Cyclops Ewarti*, Brady ; *Canuella perplexa*, Scott ; *Ameira longicaudata*, Scott ; *Acontiophorus elongatus*, Scott ; *Ectinosoma Herdmani*, Scott ; *Ectinosoma Normani*, Scott ; *Ectinosoma elongata*, Scott ; *Cancerilla tubulata*, Dalzell ; *Lepeoptheirus pectoralis*, and *Anchorella appendix*. Also one species new to science, viz., *Pseudocyclopia stephoides*, n. sp. This crustacean has not yet been described, but its description and figure will be shortly published in the "Transactions of the Liverpool Biological Society." It combines some of the characters of the genus *Stephos* with those of *Pseudocyclopia*, the latter predominating sufficiently to determine its position in that genus.

'Surface tow-nets have been continuously employed during the several marine expeditions undertaken by the Committee, also tow-nets attached to the rope a few fathoms above the dredge. The latter device has proved a success, collecting some good species of Copepoda as well as Cumacea and Amphipoda, which are seldom or never obtained on the surface. Amongst the Copepoda thus obtained were several specimens of *Pseudocalanus armatus*, found along with a shoal of *Pseudocalanus elongatus*. A widely extending shoal of *Anomalocera Patersonii* was observed off the Isle of Man in May, the only occasion on which we have taken this species during the year. On several occasions, notably in the early part of June, the surface organisms have been singularly scarce.

'Special care has been taken to wash and sieve through fine silk as much as possible of the material brought up by the dredge during marine expeditions, and it is by this means that several of the above-mentioned Copepoda new to the district have been obtained, as well as the new species *Pseudocyclopia stephoides*. Large quantities of ophiuroids, chiefly *Ophiocoma nigra* and *Ophiothrix fragilis*, are amongst the dredged material, and it is probably from one or other of these that the two specimens of *Cancerilla tubulata*, Dalyell, a male and female, were taken, as the species is parasitic on ophiuroids. The first record of this rare copepod occurs in Dalyell's "Powers of the Creator," 1851, and it has since been taken by Mr. Gamble at Plymouth, and by Mr. Scott in the Forth, but not before in our district. *Cyclops magnoctavus*, Cragin, was found along with quantities of *Temorella affinis* and *Tachidius brevicornis* in tow-nettings taken by Mr. Ascroft in low-water marine pools at Lytham. These being brackish species, it is evident that a considerable amount of fresh water finds its way into the Lytham pools.

'*Cyclops Ewarti*, Brady, although first taken in the Forth estuary, was suspected by Brady to have a fresh-water origin. Ours are evidently strictly marine, two specimens, both males, having been dredged at 20 fathoms by Mr. Thompson off Port Erin.

'Professor Herdman's fish laboratory has yielded two species of parasitic

Copepoda, viz., *Lepeoptheirus pectoralis*, found on the flounder, taken off Morecambe, and also from *Arnoglossus megastoma*, and *Anchorella appendix* from the gills of the hake.'

Mr. A. O. Walker reports as follows upon the HIGHER CRUSTACEA :—

'Collections have been examined from the following places, viz.—

'1. Off Port Erin at various points, dredged in (usually) 10 to 20 fathoms by Professor Herdman and Mr. I. C. Thompson in August and September 1893, and March 1894.

'2. Off the Little Orme, North Wales, 5 to 10 fathoms, in October 1893 (dredged by A. O. Walker).

'3. In the Menai Straits, near the Suspension Bridge (both above and below), on April 2 and May 31, 1894 (dredged by A. O. Walker).

'The following additions have been made to the list published in last year's report.

'BRACHYURA.

'*Gonoplax rhomboides*, Linn., one specimen on July 7, 1894, on mud, 45 fathoms ; 7 miles W. of Niarbyl, Isle of Man.

'*Atelecyclus septemdentatus*, Mont., two specimens from N.W. of Port Erin, 22 fathoms, on July 8.

'*Pisa biaculeata*, Mont, off Port Erin, Easter, 1894.

'MACRURA.

'*Palæmonetes varians*, Leach, in a small pool by the Afonganol, Colwyn Bay, in company with *Neomysis vulgaris*. The pool had probably been filled by a combination of flood in the little river and a high tide, but seemed to have been long cut off. The pool was full of *Ruppia maritima*. The *Palæmonetes* were 40 mm. long, and females had ova in the pouches ; the *Neomysis*, on the other hand, were small, females with ova being only 14 mm. long.

'SCHIZOPODA.

'*Leptomysis lingvura*, Sars, Colwyn Bay, in tidal pools ; and Port Erin.

'CUMACEA.

'*Nannastacus unguiculatus*, Bate, one specimen from Menai Straits.

'*Campylaspis macrophthalma*, G. O. Sars, one female from 4½ miles west of the Cronk, July 8, 1894, 22 fathoms. This is a Mediterranean species, new to Britain.

'*Petalosarsia declivis*, Sars, 8 miles W. of Fleshwick Bay, 33 fathoms ; 14 miles N.W. of Liverpool N.W. Lightship (A. Scott). This species, first recognised in our district by Mr. Scott, is only known elsewhere in British seas from the Firth of Forth and the Moray Firth.

'ISOPODA.

'*Anthura gracilis*, Mont., off Port Erin.

'*Conilera cylindracea*, Mont., off Port Erin.

'*Cymodoce truncata*, Leach, off Port Erin.

'AMPHIPODA.

'*Lysianax longicornis*, Lucas; Menai Straits.

'*Nannonyx spinimanus*, n. sp., Menai Straits, differs from the only other known species in the following points: Anterior coxal plates about the same depth as the body; eyes very large, dark brown; propodos of first gnathopod with five or six strong denticles on the hind margin; third joint of last pereiopods but little expanded behind; maxillipedes also different.

'*Tryphosa nana*, Kr.; Menai Straits.

'*Socarnes erythrophthalmus*, Robertson; Port Erin, 15 to 20 fathoms, March 24, 1894; Menai Straits.

'*Urothoë brevicornis*, Bate; off Kitterland, 20 fathoms, one male.

'*Phoxocephalus Fultoni*, Scott; Port Erin, 15 to 20 fathoms; Menai Straits.

'*Ampelisca macrocephala*, Lilljeborg; Port Erin.

'*Metopa Alderi*, Bate; Menai Straits, large specimens, male and female, 6 mm. This species has not been met with in the L.M.B.C. district, except at Puffin Island.

'*Metopa rubrovittata*, Sars; Menai Straits, Little Orme.

'*Leucothoë Lilljeborgii*, Boeck; Port Erin, 15 to 20 fathoms.

'*Monoculodes carinatus*, Bate; Port Erin, outside harbour.

'*Stenopleustes nodifer*, Sars, erroneously reported last year as *S. Malmgreni*, Boeck. In the specimens taken the elevated lobes on the hind dorsal margin of the first two pleon segments were reduced to a mere emargination of the segment.

'*Lafystius sturionis*, Kröyer, one specimen from the Liverpool Fisheries Laboratory, found under the pectoral fin of a cod.

'*Iphimedia minuta*, Sars; Colwyn Bay, Port Erin.

'*Eusirus longipes*, Boeck; Port Erin.

'*Dexamine thea*, Boeck; Port Erin Harbour.

'*Tritæta gibbosa*, Bate = *T. dolichonyx*, Nebeski, ♂. Very abundant among sponges, Menai Bridge. All the specimens that had the elongated flagellum and furred upper surface of the peduncle of the lower antennæ characteristic of the adult male had also the peculiar notched anterior margin of the propodos of the first gnathopods as in *T. dolichonyx*, while none of the females or young had it. I believe I have once seen an adult male (dug out of the test of an ascidian) with the first gnathopod as in the female. This may possibly be a case of dimorphism.

'*Liljeborgia pallida*, Bate; Port Erin.

'*Mæra semiserrata*, Bate; Port Erin.

'*Mæra Batei*, Norman; Port Erin.

'*Guernea coalita*, Norman; Port Erin, 15 and 20 fathoms.

'*Leptocheirus pectinatus*, Norman; Port Erin, Menai Straits.

'*Autonoe longipes*, Lilljeborg; Menai Bridge.

'*Janassa capillata*, Rathke; Port Erin.

'*Podocerus cumbrensis*, Stebbing and Robertson; Menai Straits, Colwyn.

'*Colomastix pusilla*, Grube; Menai Straits.

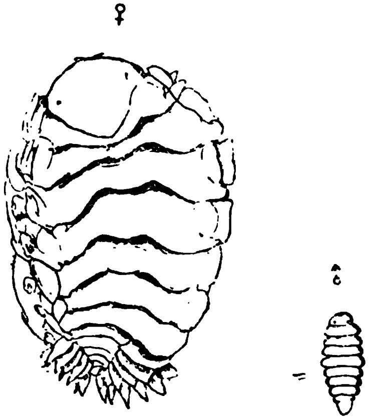
'*Corophium crassicorne*, Bruzelius; Little Orme.

'*Corophium Bonellii*, Milne Edwards; Little Orme, Port Erin.

'There still remains a quantity of material to be examined.'

The Bopyrians parasitic upon Galatheas, which were referred to in last report, have since been identified by Rev. T. R. R. Stebbing as *Pleurocrypta galateæ*, Hesse, *Pl. intermedia*, Giard and Bonnier, and *Pl. nexa*, n. sp., from *Galathea nexa* (see fig. 1). They are all on the right-hand side of the hosts' carapace, and all laden with eggs.

FIG. 1.—*Pleurocrypta nexa*, Stebbing, male and female (from a drawing kindly sent by Mr. Stebbing).



Mr. Alfred Leicester of Southport, who has taken part in most of the expeditions, and has collected and identified the Mollusca, reports that the year's work has added fifty-one fresh records to the lists for the southern part of the Isle of Man, and that of these the following nine are new to our district of the Irish Sea :—*Cardium minimum*, Phil., *Psammobia vespertina*, Chem., *Scrobicularia nitida*, Müll., *Chiton marginatus*, Penn., *Propilidium ancyloides*, Forb., *Rissoa inconspicua*, Ald., *Cæcum trachea*, Mont., *Aclis Gulsonæ*, Ch., and *Philine angulata*, Jeff.

Finally two additions have been made to our list of local fishes, viz., *Zeugopterus unimaculatus*, four specimens trawled 10–12 miles west from Morecambe Bay Lightship in May, depth 23 fathoms ; and *Gobius pictus*, Malm, caught by Mr. Walker in shore pools at Colwyn Bay.

THE SUBMARINE DEPOSITS.

Turning now to the submarine deposits, the determination and distribution of which the Committee feel to be a very important part of their work, it is still too soon to attempt anything like a detailed account of the floor of the Irish Sea, but still sufficient observations have perhaps been made to warrant the following preliminary account. The accompanying chart (Plate I.) shows the zones of depths in the district, 0–10 fathoms, 10–20 fathoms, 20–50 fathoms, and upwards of 50 fathoms, being separated from one another. At those places where the Committee (or the Liverpool Marine Biology Committee) have obtained samples of the bottom, conventional symbols are placed on the chart[1] indicating, ○ stones, △ shells, ▭ mud, ☒ sand, × nullipore deposits (*Melobesia* and *Lithothamnion*), and ⧖ shell concretions. The chief conclusions we have arrived at so far are :—

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[1] One mark frequently stands for a number of different dredgings in the same neighbourhood.

1. The most extensive shallow-water deposit is sand. In most localities along the coast of Lancashire, Cheshire, and North Wales, from the sea-shore out to the 10-fathom contour the bottom is formed of more or less pure quartz sand. Occasionally in spots there are local patches of stones, of shells, or of mud ; but these can generally be accounted for by tidal or estuarine currents, by the entrance of fresh-water streams carrying down alluvium, or by the presence of littoral or sub-littoral boulder clay. These spots are all, however, of small area, and the great extent of the bottom down to 10 fathoms is sand.

2. Further out, however, between 10 and 20 fathoms, the sand becomes greatly mixed with mud, and much diversified by large tracts of shelly deposits or by patches of gravel, and the fauna on the bottom also becomes much more abundant. In some spots, at about 20 fathoms, it is made up over considerable areas almost entirely of ophiuroids (*Ophiocoma nigra* and *Ophiothrix fragilis*), which fill the dredge haul after haul. At two localities off the Isle of Man, viz., along the east coast from Clay Head to St. Ann's Head, and off the west coast between Contrary Head and Niarbyl, at depths between 10 and 20 fathoms, are great nullipore deposits formed of *Melobesia* and *Lithothamnion*, which have a most characteristic appearance, smell, and fauna.

This area of the sea-bottom, from 10 to 20 fathoms, extends across from the north of Lancashire to the Isle of Man, so that opposite Barrow, for example, there is a wide extent of about 50 miles in length of sea-floor at depths of not more than 15 or 16 fathoms (see section at foot of Plate I.).

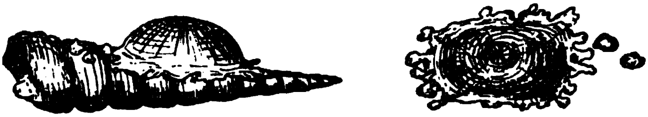
3. Depths of over 20 fathoms are only found to the west, north, and south of the Isle of Man (see Chart, Plate I.) ; and depths of from 20 to 50 fathoms give us the most varied bottom deposits and the richest fauna. As a rule the sand is more or less mixed with mud, and as the bottom goes deeper the amount of mud gets greater. When there is a considerable admixture of mud with coarse sand, that forms what is known to the trawlers as a 'reamy' bottom, and that is the ground upon which the sole and some other fish are generally found spawning.

Shells and other hard parts of animals play an important part in the deposits at depths of about 20 fathoms and upwards. In places the dredge comes up filled with Pecten shells, dead and alive, chiefly *P. opercularis* and *P. maximus*. At other places the deposit is practically composed of the shells of *Pectunculus glycimeris*. These and other shell beds form a rich collecting ground to the naturalist, as they support an abundant and varied fauna. Zoophytes and polyzoa are attached to the shells, and these serve as shelter for nudibranchs and other small mollusca, worms, and ascidians. On the whole the heterogeneous deposits support a richer fauna than do the homogeneous deposits, such as sand or mud, and it is chiefly in the zone of depth we are now considering that the heterogeneous deposits occur.

4. The depths over 50 fathoms contain a pure dark bluish grey mud which is very tenacious, and sets when dried into a firm clay. This is abominable stuff to dredge in and to work with on deck. It clings to everything that touches it : it is almost impossible to see what is in it, and to get the animals out of it uninjured ; it is too solid for the sieves, and the

hose can be played upon masses of it almost indefinitely without dissolving it. The fauna of this zone is, in our district, quite peculiar and characteristic. In its shallower parts, about 50 fathoms, it contains great numbers of living and dead *Turritella terebra*, upon many of which are attached one, two, or three specimens of the little red anemone *Sagartia Herdmani*, Haddon. In its deeper parts, up to 80 fathoms, are found *Calocaris Macandreæ*, *Hyalinœcia tubicola*, a small *Lumbriconereis*, *Panthalis Oerstedi*, *Lipobranchius Jeffreysii*, *Brissopsis lyrifera*, *Amphiura Chiajii*, and *Isocardia cor*. Great quantities of large sausage-like muddy tubes, formed of stratified layers of interlacing threads of mucus in which the mud particles are closely entangled, are brought up in the dredge. These are almost certainly the tubes of *Panthalis Oerstedi*, and the living annelid has several times been found in the tubes, but most of those we dredge up are empty, and the tubes are certainly far more numerous than the worms. Possibly the explanation is that the *Panthalis* forms a tube as it lies in the mud, and then when it moves away leaves its tube behind it (one can scarcely imagine the animal dragging such a tube through this tenacious deposit), and after a time forms another in a new situation.

FIG. 2.—*Sagartia Herdmani* (Haddon).



These are the leading conclusions we have come to so far in regard to the distribution of submarine deposits in our area. Two further questions now present themselves: first, the biological one—the effect upon the fauna; and secondly, the geological one—the origin of the deposits. In regard to the importance of the nature of the bottom to the animals living upon it there can be no doubt. Probably the nature of the deposit is the most important of the various factors that determine the distribution of animals over the sea-bottom within one zoological area. It is certainly more important than mere depth; a muddy bottom will support a similar fauna at ten fathoms in one place and at fifty fathoms in another. Probably the most important influence in the environment of a lower animal is its food, and once beyond the narrow sub-littoral zone in which algæ flourish—and to which, of course, certain phytophagous animals must be restricted—it is probably chiefly the nature of the bottom which determines the food.[1] Many animals feed upon the deposit, others browse upon the polyzoa and zoophytes which can only attach themselves and grow where there are sufficiently large objects, such as shell valves, from which they can get the necessary stability; while others, again, feed upon their neighbours, which subsist on the deposit or are attracted by the zoophytes, &c.; for example, soles are frequently caught upon ground (known to fishermen as 'sole ground') where *Flustra foliacea* lives in abundance, and the probable connection is that the fish are dependent upon the numerous amphipoda and other small animals which frequent the tufts of *Flustra*. The same locality may vary so much from time to time in the temperature, the salinity, and the transparency of the water, that it is probable that none of these factors—so long as the variations do not exceed certain limits—have so much influence upon the fauna as the nature of the deposit has. It is therefore quite to be expected that the fauna should vary from place to place with the nature of the bottom, and that is what we have observed frequently in our work round the Isle of Man. In practically the same water, identical in temperature, salinity, and transparency, at the same depth, with, so far as one can see, all the other surrounding conditions the same, the fauna varies from place to place with changes in the bottom—mud, sand, nullipores, and shell beds, all have their characteristic assemblages of animals.

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[1] The only food supply quite independent of the bottom is dead plankton, from the water above, which may reach the bottom uneaten.

As to the further, and very important, question of the origin of the deposits, that is partly a geological inquiry, and one which cannot, until we have accumulated a much larger series of observations, be fully discussed; but there are a few matters which may be briefly pointed out as giving some idea of the range and bearing of the question.

1. It is necessary to make a most careful examination of the deposits. For example, all muds are not the same in origin. A deposit of mud may be due to the presence of an eddy or a sheltered corner in which the finer particles suspended in the water are able to sink, or it may be due to the wearing away of a limestone beach, or to quantities of alluvium brought down by a stream from the land, or to the presence of a submerged bed of boulder clay, or, finally, in some places to the sewage and refuse from coast towns.

2. We have kept in view the possibility of some correlation between the geological formations along the beach and the submarine deposits lying off the shore. There is no doubt that the nature of the rock forming the shore has a great influence upon the marine fauna, and has sometimes *some* effect upon the neighbouring deposits. For example, the contrast between the deposits lying off the two prominent headlands, the Great Orme, in North Wales, and Bradda Head, in the Isle of Man, is well marked. The Great Orme is composed of mountain limestone, and the result of its weathering and erosion is that large blocks are found lying scattered outside its base on the fine sand; but there is no deposit of smaller stones, gravel, and resulting sand farther out, probably because in the wearing of the rock and the large detached blocks by the sea a great deal is removed in solution and the rest in suspension as very fine mud—this we have found to be the case round Puffin Island, which is also mountain limestone. Bradda Head, on the other hand, is a schistose metamorphic Silurian rock, which breaks up into large fragments, and these into smaller, and so forms deposits of dark slatey more or less angular gravel, and then very coarse sand, extending for some way out from the foot of the cliff.

The influence of the shore rocks upon the littoral fauna is an important subject upon which we have accumulated some observations; but the matter requires further work and detailed discussion, and must be left over for a future report.

3. Probably the great bulk of the siliceous sand which forms so large a part of the floor of our sea is derived proximately—whatever may have been its ultimate source[1]—from the great deposits of drift which were formed in the neighbourhood during the Glacial period, and large tracts of which may since have been broken up by the sea.

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[1] Probably, to a great extent, Triassic sandstones.

4. As examples of a few peculiar and specially noteworthy deposits which are not simply 'terrigenous' in their origin, the following may be mentioned :—

South-east of the Calf Sound, about two miles out, at a depth of 20 fathoms, there is a white shelly sand which seems to be almost wholly composed of animal remains. There are broken fragments of the lamellibranchs *Pecten*, *Anomia*, *Pectunculus*, *Mactra*, *Venus*, and *Mytilus*, of the gastropods *Cypræa*, *Buccinum*, *Emarginula*, *Purpura*, and *Trochus*, of various calcareous polyzoa such as *Cellaria fistulosa*, *Cellepora pumicosa*, and lepralids, of *Balanus* and *Serpula*, and of various echinoderm plates and spines, and the whole shells of *Echinocyamus pusillus*. The deposit, when it comes up in the dredge, is of a gleaming whiteness, and has a very characteristic appearance. Such a deposit as this would form a rock almost wholly made up of fossils, and might compare well with some Tertiary fossiliferous deposits, such as the Coralline Crag.

A little further north, along the east coast of the Isle of Man, at about a corresponding depth and distance from land, we meet with a purely vegetal deposit formed of the nullipores *Lithothamnion* and *Melobesia*. On the other side of the island, again, between Port Erin and the Calf, at a depth of 18 fathoms, there is a tract of sea-bottom which, when brought up on deck, looks at the first glance like a peculiarly fibrous sand, but a closer examination shows that it is entirely composed of the comminuted plates, and especially the spines of echinids, chiefly *Spatangus*.

The variety that is noticed in submarine deposits round the Isle of Man, from depths of 15 to 35 fathoms, as brought up in the dredge is very striking. It is remarkable how differing proportions in the mixtures of sand, gravel, and shells give rise to very different colours and general appearance in the mass. As seen when tumbled out of the dredge on to the deck, some deposits are white, some yellow, some grey, some reddish, of various tints from pink to ruddy brown, and others darker, of all shades of brown and dark grey. It is curious how, even in a composite deposit made up of many different constituents, there is usually a prevailing tint; for example, the bottom at Station 6 on May 27, although composed (see p. 321) of mud, sand, nullipores, shells, and stones, was distinctly of a rich ruddy brown tint. The importance of this presence of prevailing colours in the various submarine deposits is obvious in its bearing upon the colours and habits of animals.

Another very remarkable sea-bottom is one which takes the form of irregular calcareous masses, cementing together the dead shells and sand grains which are lying on the bottom, and making lumps like 'clinkers.' Hence the spot where it is found is called by the trawlers the 'Blacksmith's Shop.' It is about 25 miles S.S.W. of the Calf of Man (see Pl. I.), in ordinary clear weather the Chicken Rock Lighthouse just dipping and the stack at Holyhead just rising above the water, and the depth is about 25 fathoms. We have also heard of a similar bottom of cemented shells between Ramsey and North Lancashire. Mr. Leicester has found the following shells in the concretions :—*Pecten opercularis*, *Cyprina islandica*, *Venus lincta*, *Cardium echinatum*, *Nucula nucleus*, *Scrobicularia alba*, *Lucina borealis*, and *Turritella terebra*. There is a fine lump of this deposit in the Biological Station at Port Erin, and we have presented another piece to the Jermyn Street Museum in London. Mr. W. W. Watts, of the Geological Survey, has made a careful examination by thin sections of the latter specimen, and he has kindly sent the following notes in regard to it:—'The microscopic examination shows that it is practically a fine-grained grit made up of the usual constituents of fragmental rocks cemented together, the cement being in greater quantity than the grains. These grains are chiefly chips of quartz, but I have also seen microcline, orthoclase felspar, plagioclase felspar, brown mica, a few grains of glauconite, and green and brown pseudomorphs, probably after grains of some ferro-magnesian mineral like augite, hornblende, or even possibly olivine—which it is impossible now to say, but I think most probably hornblende. There are one or two opaque grains, and several clear grains containing a good deal of minute magnetite. The grains vary in size within small limits; the largest I have measured is 0·02 inch and the smallest 0·002 inch, but the average size would be about 0·004–0·005 inch in longest diameter. They are therefore minute grains, and, as might be expected, extremely angular, not one in a hundred showing rounded outlines. They are chiefly such grains as would come from the denudation of granitic rocks or sediments derived from them.

'The cement is carbonate of lime, with a small impurity of carbonate of iron, present chiefly in certain layers, but not there in any considerable quantity. The cement is clearly crystalline in immediate contact with the grains, and also where lining cracks and cavities. Elsewhere it is more opaque, and less conspicuously crystalline. The section cuts across numerous shell fragments and a few polyzoa, and where there are any hollow structures, as in the inside of lamellibranchs or gastropods, they are filled up with a substance indistinguishable from the bulk of the concretion.

'The specimen shows no particular reason for the local deposit of cement, and the other constituents are doubtless the ordinary materials of the sea-bed. I cannot find any evidence that the cementing is due to any organic agency, and the thoroughly well-developed crystals of carbonate of lime quite agree with this. It may be that the Carboniferous limestone crops out on the sea-bottom under the deposit, and, if so, there would very likely be submarine springs laden with carbonate of lime which might be precipitated there under less pressure or local loss of carbonic acid. It may be added that Mr. Clement Reid could not see in the specimen any identifiable shells of other than recent age.'

Another possible explanation is that the smaller calcareous particles on the bottom have been dissolved in the sea-water and then re-deposited so as to cement together the larger shells and the sand grains.

As was mentioned earlier in the report, sample bags of all the more important submarine deposits we have come upon have been sent, at Sir Archibald Geikie's request, to the Museum of the Geological Survey in Jermyn Street. They are being examined there by Mr. Clement Reid, F.G.S., who writes the following preliminary note in regard to them:—

'On comparing these samples with British deposits of Tertiary date one finds a marked difference in lithological character. Dredgings from the Irish Sea, and also from the North Sea, are characterised by a much coarser and more gravelly texture than one would expect at such depths—coarser, in fact, than one finds in Pliocene deposits, yielding a similar fauna, indicating similar or even smaller depths. A glance at these dredgings shows the reason of this, for they are largely composed of unworn or little-worn fragments of rock, often entirely encrusted by organic growth. The stones evidently have not been transported far by water, or they would be well rounded, like the pebbles found in our Eocene beds. The encrusting organisms show also that the fragments have lain undisturbed on the sea-bed, yet they have often been derived from far-distant sources. Though no Glacial striæ were observed, and no undoubted sub-fossil arctic shells have yet been found at these localities, yet there seems little doubt that the bulk of the material on the sea-bottom over this area has been derived from the breaking up of pre-existing Glacial deposits. This may occur at a depth of several fathoms through the gradual washing away of the muddy and sandy matrix of a boulder clay or Glacial gravel. Coarse gravel is thus caused to accumulate at a spot where the currents may be too feeble to transport anything but sand.

'This submarine origin of angular gravel deposits should not be forgotten, for it affects the lithological character of the sea-bottom over most of the area which was formerly glaciated, even as far south as Cornwall. On the other hand, it does not affect, except to a small extent, the sea-bed beyond the former limit of the ice, and it does not affect pre-Glacial deposits. Thus we must always expect to find at similar depths the same fauna associated with deposits of finer texture as soon as we leave the glaciated area, or when we go back into Tertiary times.

'It is also worth noting that the occurrence of a stony bottom at twenty or thirty fathoms—where normally there would be no deposit coarser than sand—will probably lead to a disproportionate increase of all encrusting organisms, and of all organisms needing a solid base. This has certainly taken place, as anyone studying our shoal-water Tertiary deposits will have observed. They contain few stones, and though each stone or dead shell may be covered with encrusting organisms, yet the relative proportion of these to the free forms is far smaller than seems commonly to be the case in the seas that now wash our shores. The sole exception to this rule among the British Tertiary strata is found in the Coralline Crag, in which the contemporaneous consolidation of the limestone was sufficient to provide the necessary solid base for the encrusting and fixed organisms so abundant in that deposit.'

In conclusion, it is clear that this investigation of our modern submarine deposits, their distribution, nature, origin, and associated fauna, has geological applications, and that our results may be of some importance to palæontologists in determining the conditions under which the fauna of a particular horizon existed in the past; but, from our point of view, the matter is a purely Biological one. We consider it of primary importance, in studying the distribution of the marine animals in our district, to investigate as minutely as possible their environment, and that not merely because it gives us some of the factors and possibly the explanation of the distribution, but also on account of the light it may throw upon the habits, variations, and other important characteristics of the species.

The Committee apply to be reappointed, with a small grant to defray part of the expenses of the dredging expeditions.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Dr. P. L. SCLATER, Professor E. RAY LANKESTER, Professor J. COSSAR EWART, Professor M. FOSTER, Mr. A. SEDGWICK, *the late* Professor A. M. MARSHALL, *and* Mr. PERCY SLADEN (*Secretary*).

APPENDIX PAGE
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II.—*A List of Naturalists who have worked at the Zoological Station from the end of June* 1893 *to the end of June* 1894 340
III.—*A List of Papers which have been published in the year* 1893 *by the Naturalists who have occupied Tables at the Zoological Station* . . 341

DURING the past year the table hired by the British Association in the Naples Zoological Station has been occupied by Mr. J. E. S. Moore, and your Committee have pleasure in directing attention to the important investigations carried on by him, and to the carefully worked-out results which are indicated in the accompanying report sent in by Mr. Moore. In the opinion of your Committee this report alone is sufficient to justify them in strongly recommending the renewal of the grant.

An application for permission to use the table during the ensuing year for a period of six months, commencing at the end of September, has been received from Mr. M. D. Hill, who wishes to continue his researches on fertilisation in the eggs of Echinoderms, Mollusks, and Annelids. Your Committee hope that the Association, by continuing the hire of a table as in previous years, will enable them to afford to their applicant and to other British naturalists the chance of participating in the advantages of this justly predominant and well-managed institution. In further support of this expression the Committee beg to lay before the Council the cogent remarks of Professor Anton Dohrn contained in the following letter addressed to their Secretary. This letter furnishes at the same time a report—by the one best qualified to give it—of the present position of the station, as well as a statement of its claims upon the naturalists of other countries, and especially upon all broad-minded scientific workers who advocate the importance of international co-operation :—

Naples: July 5, 1894.

DEAR MR. SLADEN,—To give in a few words my report on the progress of the Naples Zoological Station, I may be permitted to say, '*Vivit, floret, crescit*' in all its parts.

In fact, this is the plain truth : the life of the station is best proved by the number of those who use its opportunities for research ; its flourishing state by the quality and the quantity of scientific publications produced there in the course of one year ; and its growth by the addition of new arrangements for library, laboratory, and administration. As figures speak for themselves, I may add that 800*l.* sterling have been spent this year for the latter purpose alone.

All this is too well known by those who take an interest in the development of this institution to require a new or detailed explanation. What is less generally known, but often considered by the best and most confiding friends of the Zoological Station as the greatest drawback and danger in its whole constitution, is the uncertainty in which its future lies. The fact that individual initiative and individual responsibility have hitherto been appealed to exclusively for the existence of the Zoological Station has caused in many minds apprehension as to what might befall such a highly complex organisation if individual initiative and responsibility should become unable, by the natural course of events, to guarantee its further development, and even its existence.

At the last International Medical Congress in Rome a voice was heard pointing out the danger which threatened the Zoological Station, and this voice was that of my friend Professor Michael Foster, of Cambridge. I venture to make a few remarks on what my friend Foster said on that occasion. Speaking of the desirability—nay, the necessity—of international organisation, he said: 'An example of this is the work done at the Zoological Station at Naples. This is in reality an international institution, although it has been chiefly originated by one man; such an institution ought to be international, and ought not to depend for its existence upon the energy of one man.' In thanking Professor Foster heartily for the credit which he gives me for originating the station, I must after all express my belief that the Zoological Station will, even in the future, find it safest to depend upon one man's energy, if the one man is ready and able to take upon himself the burden of the responsibility. It will take some time before the ideal of which Professor Foster spoke—'international organisation of science'—can be realised. We are still too deeply imbued with national prejudice and national ambition to acknowledge readily any scheme which might be offered to help science by combined international action. I have had on many occasions to experience the power of these influences during my career at the head of the Zoological Station, and even now I can hardly say that the character attributed by Professor Foster to the Zoological Station is so firmly established as to justify fully the title *international*. *De facto* it is Germany which pays half the sum necessary for the maintenance of the Zoological Station at Naples, though Germany does not claim any privilege over other contributors. I tried to arrange with the Prussian Ministry of Public Instruction for a transfer of the direction of the station in case of my death or inability; it was not, however, accepted on account of the difficulty of governing an institution of this complex nature without endangering its cosmopolitan character. On the other hand, many countries receive direct or indirect advantages from the existence of the Zoological Station at Naples, but do not accept any or a due share of the burden of its maintenance.

Years ago I undertook to organise the 'Zoologischer Jahresbericht' on the footing of international contributions, and failed to such an extent that I had almost to give up the whole Jahresbericht. National prejudice and private interest could not be moved to give way to higher aims. I could easily furnish interesting material in regard to the manner in which these endeavours came to be frustrated, but I will rather defer it to another occasion, since I am still resolved to try again, and perhaps on a greater scale, the undertaking which failed fifteen years ago. Professor Foster's own speech and many other utterances of authoritative character prove undoubtedly that what I attempted in 1879 will soon be generally taken up, and will doubtless prove one of the most important steps in the organisation of science. Meanwhile I have been busy preparing for the continuance of the station's monarchical constitution by winning over the municipal authorities of Naples to revise the original contract, which did not give me the right to establish the inheritance of the Zoological Station on one of my four sons. The revision has now been carried through, and my eldest son is directing his studies in order to be prepared to continue the administration of the station when the time comes that his father is unable to carry it on. The right of inheritance being extended to all my four sons, I hope the future of the Zoological Station will be considered somewhat better established now than it was some years ago.

I am further endeavouring to render the task easier for my sons by collecting funds, which may serve as a reserve and pension fund for times of depression, or when age and disease should deprive me and the station of the valuable co-operation of any of my faithful staff, thus establishing the station on the footing of an industrial or commercial enterprise, but without the drawback of having to pay dividends to shareholders. The progress made in this direction is naturally slow and only possible with Germany's generosity; but it is to be hoped that such funds once established, and their existence made known, even private help may be obtained for their more rapid increase.

In giving you this information, dear Mr. Sladen, I hope rather to augment than to diminish the readiness for help which, from the very beginning, the Zoological Station has met with in Great Britain, and to facilitate the maintenance of the table which the British Association has so many years kept up in an institution which has become—Professor Foster's own words prove it—a forerunner of many other institutions to be created in the next century on an international basis for the promotion of research.—Yours sincerely,

ANTON DOHRN.

The progress of the various publications undertaken by the station is summarised as follows :—

1. Of the 'Fauna und Flora des Golfes von Neapel,' the monographs by Professor Spengel on 'Enteropneusta' (758 pp., 37 plates), and by Professor Della Valle on 'Gammarini' (948 pp., 61 plates) have been published ; and the monograph by Dr. W. Müller on 'Ostracoda' is nearly ready.
2. Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' vol. xi., parts i. and ii., with 13 plates, have been published, and part iii. is in the press.
3. Of the 'Zoologischer Jahresbericht,' the whole 'Bericht' for 1892 has been published, and the 'Bericht' for 1893 is nearly ready. There is also in the press an Alphabetical Index for the years 1886 to 1890.
4. A new edition (entirely rewritten) of the 'Guide to the Aquarium' (in German) is being prepared.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers, will be found at the end of this report. They embrace lists (1) of the naturalists who have occupied tables since the last report; and (2) of the works published during 1893 by naturalists who have worked at the Zoological Station.

The preserved specimens sent out by the station during the year ending June 1894 comprised 194 consignments, amounting to 17,687.70 fr., as against 171 consignments, amounting to 13,334.95 fr. in the preceding year.

APPENDIX.

I.—*On the 'Reduction Division' in the Cartilaginous Fishes.*
By J. E. S. MOORE.

In availing myself of the unrivalled opportunities for investigation offered by the marine laboratory at Naples, I had in view the continuation of some researches, concerning the nature of the origin of the reproductive elements in forms which it was difficult to obtain under suitable conditions while at home.

No great amount of reliable descriptive matter relating to the origin and anatomy of the reproductive cells is really available from a modern cytological standpoint; but notwithstanding this paucity of material wherewith to build, the intellectual activity of the time has been able to fit it to a vast superstructure of speculation which in the minds of not a few observers of to-day has only been built to fall.

Wherever theory far outstrips the facts, and by its own light penetrates where actual observation has not yet been made, its explanations are always subject to a long and close revision, as the bricks of the actually known mount up and their theoretical substitutes are individually weighed and left to stand or thrown away as wanting.

The demonstration of a number of nuclear chromosomes constant for each species both for animals and plants was no sooner found to be a universal truth than the discovery of a reduction by one half of this number in the origin of the two pronuclei, as described by Hertwig in the case of *Ascaris*, led up to the belief that in this phenomenon lay the secret of that blending of hereditary characters which naturalists had so long sought in vain.

In the case of the invertebrates in which the reduction divisions were first described, the chromosomes are said to pass undivided to the daughter cells in such a way that there are only half as many in these as in the parent, and the assumed universality of this phenomenon forms the keynote of that part of Weismann's theory which deals with the balancing of the hereditary stuffs at fertilisation. Some experience of the phenomenon of maturation in the spermatogenesis of Mammalia had convinced me that, although there was a numerical chromatic reduction, this phenomenon was brought about in a manner quite different from what was generally supposed; and I determined during my stay in Naples to study the same phenomena as presented in Elasmobranchs, so that we should be able to arrive at definite conclusions in another great group of vertebrates.

It had been my intention at the same time incidentally to make an embryological study of the developmental histology of the whole reproductive gland, but the limited amount of material available for this purpose necessitated the restriction of my work to somewhat narrower lines.

A preliminary account of this was published in the 'Anatomische Anzeiger,' in a note 'On the Germinal Blastema and the Nature of the so-called "Reduction Division" in the Cartilaginous Fishes,' which I had completed on February 28. During March, April, and May I was able to revise and extend the results I had hitherto obtained.

It will be seen that my observations respecting the reduction phenomena fit in admirably with the half theoretical anticipations of Boveri, as well as with what I had already found to be the case in the spermatogenesis of Mammalia, and what Brauer regards as the more correct rendering of the same phenomena in *Ascaris*.

The last two divisions of the Elasmobranch spermatogenesis are quite distinct from those which go before.

There are twelve chromosomes in the penultimate division, whether we count them when emerging as chromatic rings from the reticulum of the previous resting nucleus in the 'monaster,' or as the divided loops when nearing the opposite poles of the spindle figure as suggested by Boveri.

The daughter nuclei produced pass into a condition of complete repose prior to the last division of the spermatogenetic series, and the initial phases of the last mitosis, as well as its whole course, proceed in exactly the same way as in the penultimate division, except that only six chromosomes emerge from the resting reticulum instead of twelve.

A close examination of these twelve chromosomes of the penultimate division reveals the fact that they are each built up of four small condensations or primary elements united together in the form of a ring, while those constituting the individual loops or rings of the final division are far more numerous. The small size and crowding of the parts in the latter phase render counting very difficult, but numbers of readings satisfied me that in this division they are eight—i.e., the twelve fourfold chromosomes of the penultimate division are rearranged in the form of six eight-fold chromosomes in the last division, while both divisions are normal mitoses, in which there is no passage of unsplit chromatic masses to the poles.

In the spermatogenesis of this fish, then, there is reduction only in the number of the chromosomes when they reappear from this rest in the final as compared with the penultimate division. But this change is not brought about by either division; it occurs during the resting condition of the nucleus between the two, and exists simply as a rearrangement of the parts.

From Brauer's work it seems that the so-called 'reduction' in the spermatogenesis of *Ascaris* is brought about during an intervening rest between the last mitoses, just as in the case of the Mammalia, and we now have it also in the cartilaginous fish, so that it follows that in these widely separated groups the last two divisions of the spermatogenesis do not correspond to the successive extrusions of the polar bodies, because between the two mitoses which bring about this extrusion there is no rest phase, and the supposed absence of this between the last divisions of the spermatogenesis was the very fact from which Hertwig argued their similarity.

Moreover, Boveri seems conclusively to show that there is no 'reduction' accomplished in any division up to the formation of the first ovicyte, nor yet in either division by which the polar bodies themselves are formed. Yet there are only half as many chromosomes in the divisions which form the polar bodies as there are in the mitoses prior to the formation of the first ovicyte, and so *ab infra* the reduction must occur in the rest after the division which forms the cell.

If a comparison can be made at all, the spermatogenesis of the forms under discussion stops short at a point corresponding to the formation of the first ovicyte in the ovigenesis.

Such, then, are the bare facts of the chromatic reductions in these cartilaginous fishes. But it must not be supposed that they are more than the grossest features presented by a mass of material which will take many months in fully working up.

Nor yet are they in a strictly anatomical sense by any means the most interesting features in relation to these cells; the large clear elements of the Elasmobranch testes present a splendid field for more purely cytological research, and I gave the briefest account of the direction in which such investigations seemed tending in the article above referred to. Very little is really known respecting cellular metamorphosis, or the morphological value of the intercellular structures relating to it; in fact, we are only just beginning to extend morphological conceptions to cellular anatomy at all. Consequently it is with the profoundest interest that I find among other things the archoplasmic vesicle of the Elasmobranch spermatid to have an intra-nuclear origin, although it remains identical in structure and minute relationship with that of the Mammalia, a purely cytoplasmic construction.

In conclusion, I would express my thanks to the British Association for the opportunity of completing my work, and to the Directors of the Naples Laboratory for their unremitting kindness during my stay.

II.—*A List of Naturalists who have worked at the Zoological Station from the end of June* 1893 *to the end of June* 1894.

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
748	Dr. A. Russo	Italy	July 1, 1893	Dec. 31, 1893
749	Prof. A. Della Valle	"	" 6, "	Oct. 23, "
750	Prof. S. Trinchese	"	Aug. 8, "	Dec. 31, "
751	Dr. G. Mazzarelli	"	" 8, "	—
752	Stud. V. Diamare	"	" 8, "	—
753	Prof. F. S. Monticelli	"	" 8, "	—
754	Signa. B. Ferrari	"	" 2, "	Sept. 6, "
775	Sig. F. Crevatin	"	" 2, "	" 6, "
756	Mr. George Bidder	Zoological Station	" 9, "	—
757	Dr. U. Flora	Italy	" 10, "	Nov. 7, "
758	Dr. G. Zambrano	"	" 11, "	Oct. 14, "
759	Dr. N. Iwanzoff	Russia	" 23, "	Nov. 25, "
760	Prof. A. de Korotneff	"	Sept. 24, "	Oct. 2, "
761	Dr. Th. Schaeppi	Switzerland	Oct. 3, "	Dec. 1, "
762	Dr. P. Samassa	Baden	" 5, "	Apr. 13, 1894
763	Prof. G. Fornario	Italy	" 10, "	—
764	Mr. J. E. S. Moore	British Association	" 16, "	June 9, "
765	Dr. R. Whassak	Switzerland	Nov. 3, "	Mar. 17, "
766	Dr. Th. Beer	Austria	" 7, "	May 12, "
767	Mr. G. Fairchild	Smithsonian Institution	" 18, "	Mar. 17, "
768	Dr. W. M. Wheeler	" "	Dec. 30, "	Apr. 14, "
769	Prof. S. Trinchese	Italy	Jan. 1, 1894	—
770	Dr. G. Jatta	Zoological Station	" 1, "	—
771	Dr. A. Russo	Italy	" 1, "	—
772	Dr. H. Klaatsch	Prussia	" 11, "	—
773	Dr. S. Fuchs	Austria	" 21, "	June 9, "
774	Prof. H. C. Bumpus	Smithsonian Institution	" 25, "	Apr. 2, "
775	Prof. A. de Korotneff	Russia	Feb. 5, "	Feb. 14, "
776	Prof. J. Klein	Hungary	" 9, "	May 9, "

II.—A LIST OF NATURALISTS—*continued.*

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
777	Prof. R. Ewald	Strasburg	Feb. 15, 1894	May 9, 1894
778	Dr. H. Stehlin	Switzerland	„ 16, „	June 15, „
779	Cand. A. Schmidt	Holland	Mar. 1, „	—
780	Prof. H. Ludwig	Prussia	„ 4, „	Apr. 3, „
781	Dr. R. Krause	„	„ 5, „	Mar. 27, „
782	Dr. H. Duerck	Bavaria	„ 8, „	Apr. 26, „
783	Dr. E. Bruns	„	„ 9, „	„ 26, „
784	Prof. W. His	Saxony	„ 16, „	Mar. 27, „
785	Dr. W. Nagel	Würtemberg	„ 17, „	Apr. 13, „
786	Mr. J. H. Riches	Cambridge	„ 21, „	—
787	Baron J. Uexküll	Prussia	„ 22, „	June 28, „
788	Mr. E. Rice	Harvard College	„ 23, „	May 12, „
789	Dr. M. Golenkin	Russia	„ 23, „	June 26, „
790	Cand. P. Ehrmann	Saxony	„ 27, „	May 14, „
791	Mr. H. Vernon	Oxford	„ 29, „	—
792	Dr. J. F. Heymans	Belgium	Apr. 4, „	„ 10, „
793	Dr. A. Borgert	Hamburg	„ 12, „	—
794	Dr. L. Murbach	Smithsonian Institution	„ 25, „	June 23, „
795	Dr. C. Crety	Italy	May 6, „	May 16, „
796	Prof. S. Apáthy	Hungary	„ 11, „	—
797	Prof. C. W. Hargitt	Amer. 'Davis' Table	„ 19, „	—
798	Dr. G. Valenza	Italy	„ 29, „	—
799	Dr. T. List	Hesse	„ 30, „	—
800	Stud. G. Tagliani	Italy	June 1, „	—
801	Dr. C. Child	Harvard College	„ 4, „	—
802	Dr. C. C. Schneider	Saxony	„ 12, „	—
803	Dr. E. Giacomini	Italy	„ 21, „	—

III.—*A List of Papers which have been published in the year* 1893 *by the Naturalists who have occupied Tables at the Zoological Station.*

R. von Erlanger	Beiträge zur Kenntniss des Baues und der Entwickelung einiger mariner Prosobranchier. 'Zool. Anzeiger,' 1893.
C. Herbst	Ueber die künstliche Hervorrufung von Dottermembranen an unbefruchteten Seeigeleiern, nebst einigen Bemerkungen über die Dotterhautbildung überhaupt. 'Biol. Centralblatt,' 1893.
„	Experimentelle Untersuchungen über den Einfluss der veränderten chemischen Zusammensetzung des umgebenden Mediums auf die Entwickelung der Thiere. II. Theil. Weiteres über die morphol. Wirkung der Lithiumsalze und ihre theoretische Bedeutung. 'Mitth. Zool. Station Neapel,' 11. B., 1893.
A. Pasquale	Vergleichende Untersuchungen über Streptokokken. 'Beiträge zur pathol. Anatomie u. allg. Pathologie,' 12. B., 1893.
A. Willey	Studies on the Protochordata. I. On the origin of the branchial stigmata, præoral lobe, endostyle, atrial cavities, etc., in Ciona intest., etc. 'Quart. Journ. Micr. Sc.,' vol. 34, 1893.
„	Studies on the Protochordata. II. Development of the Neurohypophysical System in Ciona intest. and Clavellina lepadiformis, etc. *Ibid.*, vol. 35, 1893.
S. Bonaduce	Ueber die Beziehungen des Blutserums von Thieren zur

	natürlichen Immunität. 'Beitr. zur pathol. Anatomie u. allg. Pathologie,' 12. B., 1893.
A. Russo	Sulla connessione dello stomaco ed il circolo delle lacune sanguigne aborali nelle Ophiothrichidæ.' 'Zool. Anzeiger,' 1893.
„	Specie di Echinodermi poco conosciuti e nuovi viventi nel Golfo di Napoli.' 'Atti R. Accad. Sc. Fis. e Mat. Napoli,' vol. 6, 1893.
W. Kruse	Bemerkungen über Infection, Immunität u. Heilung. 'Beiträge zur pathol. Anatomie u. allg. Pathologie,' 12. B., 1893.
A. Goette	Vergl. Entwick.-Geschichte von Pelagia noctiluca. 'Zeitschr. f. wiss. Zoologie,' 55. B., 1893.
G. Mazzarelli	Monografia delle Aplysiidæ del Golfo di Napoli. 'Soc. Ital. di Sc.', vol. 9, No. 4, 1893.
„	Ricerche sulle Pettidæ del Golfo di Napoli. 'Atti R. Accad. Sc. Fis. e Mat. Napoli,' vol. 6, 1893.
G. Cano	Sviluppo e Morfologia degli Oxyrhynchi. 'Mitth. Zool. Station Neapel,' 10. B., 1893.
„	Dorippe. Studio morfologico. 'Atti R. Acc. Sc. Fis. e Mat. Napoli,' vol. 6, 1893.
H. Driesch	Zur Verlagerung der Blastomeren des Echinideneiss. 'Anat. Anzeiger,' 8. Jgg., 1893.
„	Entwickelungsmechanische Studien. VII. Exogastrula u. Anenteria. VIII. Ueber Variation der Mikromerenbildung. IX. Ueber die Vertretbarkeit von Ectoderm u. Entoderm. X. Ueber einige allg. entwickelungsmechanische Ergebnisse. 'Mitth. Zool. Station Neapel,' 11. B., 1893.
A. Kreidl	Weitere Beiträge zur Physiologie des Ohrlabyrinthes. I. Mitth. Versuche an Fischen. 'Sitz.-Ber. Wiener Akad.', Abth. III., 101. B, 1893. II. Mitth. Versuche an Krebsen. *Ibid.*, 102. B., 1893.
P. Knoll	Zur Lehre von den Structur u. Zuckungsverschiedenheiten der Muskelfasern. I. Zuckungsnerven von Schliessmuskeln der Lamellibranchiaten. *Ibid.*, 101. B., 1893.
„	Ueber die Herzthätigkeit bei einigen Evertebraten u. deren Beeinflussung durch die Temperatur. *Ibid.*, 102. B., 1893.
G. Antipa	Eine neue Stauromeduse. Capria Sturdzii. 'Mitth. Zool. Station Neapel,' 10. B., 1893.
G. Müller	Ueber Lebensweise u. Entwickelungsgeschichte der Ostracoden. 'Sitz.-Ber. k. Preuss. Akad. Wiss. Berlin,' 23. B., 1893.
R. Heymons	Zur Entw.-Geschichte von Umbrella mediterranea. 'Zeitschr. f. Wiss. Zool.,' 56. B., 1893.
G. Field	Echinoderm Spermatogenesis. 'Anat. Anzeiger,' 8. Jgg., 1893.
K. Zimmermann	Studien über Pigmentzellen. 1. Ueber die Anordnung des Archiplasmas in den Pigmentzellen der Knochenfische. 'Archiv f. mikr. Anat.,' 41. B., 1893.
F. S. Monticelli	Cotylogaster Michaelis. 'Festschrift Leuckart.,' 1893.
„ „	Studii sui Trematodi endoparassiti. 'Zool. Jahrb.,' Supplementheft III., 1893.
A. Newstead	On the perivisceral cavity of Ciona. 'Quart. Journ. Micr. Sc.,' vol. 35, 1893.
C. Crety	Intorno alla struttura delle ova delle Oloturie. 'Boll. Zool. ed Anatom., Univers. Torino,' v. 8, 1893.
G. Jatta	Sopra l' organo dell' imbuto nei Cefalopodi. 'Boll. Soc. Nat. Napoli,' vol. 7, 1893.
G. von Koch	Photographische Abbildungen von lebenden Seethieren. 'Mitth. Zool. Station Neapel,' 11. B., 1893.
D. Carazzi	Revisione del genere Polydora e cenni su due specie che vivono sulle striche. 'Mitth. Zool. Station Neapel,' 11. B., 1893.

A. Ostroumoff . .	Studien zur Phylogenie der äusseren Genitalien bei Wirbelthieren. I. Theil. *Ibid.*
A. Hansen . . .	Ueber Stoffbildung bei den Meeresalgen. *Ibid.*
M. Bedot . . .	Révision de la famille des Forskalidae. 'Revue Suisse de Zool.,' t. 1, 1893.
J. Schaffer . . .	Ueber den feineren Bau der Thymus u. deren Beziehungen zur Blutbildung. 'Sitz.-Ber. Wiener Akad.,' III. Abth., 102. B., 1893.
R. Hesse . . .	Beiträge zur Kenntniss des Baues der Euchytraeiden. 'Zeitschr. wiss. Zoologie,' 57. B., 1893.
V. Fausek . . .	Ueber den sog. weissen Körper, sowie über die embryonale Entwickelung desselben, der Cerebralganglien und des Knorpels bei Cephalopoden. 'Mém. Acad. St.-Pétersbourg,' t. 41, 1893.
P. Klemm . . .	Ueber Caulerpa prolifera, ein Beitrag zur Erforsch. der Form und Richtkräfte in Pflanzen. 'Flora, oder allg. botan. Zeitung,' Heft 5, 1893.
J. von Uexküll . .	Ueber paradoxe Zuckung. 'Zeitschr. f. Biologie.,' 30. B., 1893.
„ . .	Physiolog. Untersuchungen an Eledone moschata. II. Die Reflexe des Armes. *Ibid.*
F. Röhmann . . .	Ueber den Stoffumsatz in dem thätigen electrischen Organ des Zitterrochen, etc. 'Arch. Anat. Physiol.,' Phys. Abth., 1893.

The Zoology of the Sandwich Islands.—Fourth Report of the Committee, consisting of Professor A. NEWTON (*Chairman*), Dr. W. T. BLANFORD, Dr. S. J. HICKSON, Professor C. V. RILEY, Mr. O. SALVIN, Dr. P. L. SCLATER, Mr. E. A. SMITH, *and* Mr. D. SHARP (*Secretary*).

THE Committee were reappointed to continue their report on the present state of our knowledge of the zoology of the Sandwich Islands and to take steps to investigate ascertained deficiencies in the fauna, with power to co-operate with the committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance as may be offered by the Hawaiian Government.

During the past year your Committee have been harmoniously co-operating with that appointed by the Royal Society, and Mr. Perkins's labours in the islands have been satisfactorily continued. Since your Committee last reported Mr. Perkins has been diligently exploring in succession Molokai, Lanai, and Maui, from the first two of which very considerable collections in almost all branches of the terrestrial fauna have already been received, while one is shortly expected from the third. By the last accounts he was about to proceed to Kauai.

Although far from having completed the zoological exploration of the archipelago, the Committee have thought it best that Mr. Perkins should return home in the course of the autumn, and have instructed him accordingly. They hope to obtain his assistance, in conjunction with that of other competent zoologists, towards working out his extensive collections, the value of which it is difficult to over-estimate, since evidence of the growing scarcity of many, and of the extinction of not a few members of the endemic fauna becomes stronger the more the subject is investigated.

In view of making arrangements necessary for this purpose your Committee request that they may be reappointed, with the same powers as before, but they do not ask on the present occasion for any grant of money.

The Present State of our Knowledge of the Zoology and Botany of the West India Islands, and on taking Steps to Investigate ascertained Deficiencies in the Fauna and Flora.—Seventh Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Mr. GEORGE MURRAY (*Secretary*), Mr. W. CARRUTHERS, Dr. A. C. L. G. GÜNTHER, Dr. D. SHARP, Mr. F. DUCANE GODMAN, *and* Professor A. NEWTON.

THIS Committee was appointed in 1887, and it has been reappointed each year until the present time.

The Committee have to report satisfactory progress in obtaining reports on the collections made by the Committee's collectors, and this task of working out the results has engaged their exclusive attention during the year. The following reports have been published (or are complete and ready for publication) since the last annual report:—

1. Report on the parasitic Hymenoptera of St. Vincent by Messrs. Riley, Ashmead, and Howard (Linnean Society). The corresponding group from Grenada has been sent to these authors.
2. Report on the Hemiptera of St. Vincent by Dr. Uhler (Zoological Society).
3. Report on the Ants of St. Vincent by Professor Forel (Entomological Society).
4. Part III. dealing with the Diplopoda and Protoacheata of Mr. Pocock's report (Linnean Society), with a supplement on the Pedipalpi.
5. Report on the Trichopterygidæ and Corylophidæ by the Rev. M. Matthews (Annals and Magazine of Natural History).
6. Report on the Attidæ of St. Vincent by Mr. Peckham (Zoological Society).
7. Report on the Diptera of St. Vincent by Professors Williston and Aldrich (Linnean Society).
8. Report on the Hepaticæ of St. Vincent and Dominica by Richard Spruce (Linnean Society).
9. Report on the Freshwater Algæ (including those of the boiling lake of Dominica) by Mr. William West (Linnean Society).
10. Report on the Spiders of St. Vincent, Part II., by M. Simon (Zoological Society).

The report on the Musci has been completed by Mr. Gepp, and will be presented to the Linnean Society. The Marine Algæ have been named by Mr. George Murray, who does not consider the result worth separate publication, and the Lichenes (the only remaining group of plants) are in the hands of Professor Wainio for determination. The large collection of Coleoptera from St. Vincent and Grenada, numbering 27,980 specimens, has been arranged by Messrs. Sharp and Gahan, and its treatment will receive the Committee's immediate attention.

The Committee recommend their reappointment, with the following members:—Dr. Sclater (Chairman), Mr. George Murray (Secretary), Mr. Carruthers, Professor Newton, Mr. Godman, Dr. Günther, and Dr. Sharp. They also recommend that a grant of 200*l.* be placed at their disposal to enable them to continue their work and to adequately provide for the exploration of Margarita.

Investigations made at the Laboratory of the Marine Biological Association at Plymouth.—Report of the Committee, consisting of Professor E. RAY LANKESTER (*Chairman*), Professor M. FOSTER, Professor S. H. VINES, *and* Mr. G. C. BOURNE (*Secretary*).

On the Development of Alcyonium. By Dr. S. J. HICKSON.
On the Later Stages in the Development of Decapod Crustacea. By EDGAR J. ALLEN.

THE Committee were appointed for the purpose of enabling Dr. S. J. Hickson to investigate the development of Alcyonium at the Laboratory of the Marine Biological Association, Plymouth.

The Committee have received the following report from Dr. Hickson, and a supplementary report from Mr. Edgar J. Allen, who occupied the table during June and July 1893 :—

On the Development of Alcyonium. By Dr. S. J. HICKSON, M.A.

On my arrival at Plymouth early in the month of December last I experienced a great difficulty in obtaining a sufficient quantity of material, in consequence of the severe storms then raging. The few specimens of Alcyonium I obtained contained large quantities of ripe ova or sacs containing ripe spermatozoa. They spawned freely in the tanks of the aquarium, but I was not successful in fertilising the ova artificially, as the water of the tanks affected injuriously the spermatozoa. I succeeded, however, in obtaining a few young embryos by keeping the specimens in fresh sea-water in buckets. Soon after Christmas the sea became calmer and I obtained plenty of colonies, but they were nearly all spent and useless for my investigations.

The results I have obtained confirm those of Kowalewsky. I can find no trace of any karyokinetic division of the first segmentation nucleus, although these figures can be easily demonstrated in the later stages. While I was waiting for sufficient material to study the embryology of Alcyonium, I devoted a considerable amount of time to a study of the minute anatomy and physiology of the genus. A full account of these investigations will appear in a paper now nearly ready for publication.

Researches on the Later Stages in the Development of Decapod Crustacea. By EDGAR J. ALLEN, *B.Sc. London.*

My attention during the months, June and July 1893, when I occupied the Association table, was devoted chiefly to the study of the nervous system. After repeated trials on a number of decapod embryos and larvæ, a satisfactory subject for research was found in the embryonic lobster, many of the nerve elements of which stain excellently in dilute solutions of methylene blue. My observations, after being continued and extended, were published in a preliminary paper read before the Royal Society in April 1894, whilst a fully illustrated account will shortly appear in the 'Quarterly Journal of Microscopical Science.'

The following nerve-elements are amongst the most important of those which I was able to demonstrate during the time which I occupied the Association table :—

(1) Elements starting from a cell in one ganglion of the thorax and giving off a fibre, which, after sending numerous arborescent branches to

the neuropile of that ganglion, ends in a small tuft of fine branches in the next ganglion behind.

(2) Elements starting from a cell in one ganglion of the thorax, giving off a fibre which sends out lateral arborescent branches in the ganglion, passes forwards to the next ganglion, where it gives off a small tuft of branches, and finally ends in a tuft of branches in the ganglion next but one in front of that in which the cell lay.

The terminal tuft of each element lies close to the lateral tuft of the corresponding element of the next ganglion, and opposite the terminal tuft of the elements of Group 1.

(3) Elements starting from a cell in a ganglion giving off a fibre, which passes through one of the lateral nerves and finally breaks up upon a muscle.

The Influence of Previous Fertilisation of the Female on her Subsequent Offspring, and the Effect of Maternal Impressions during Pregnancy on the Offspring.—Interim Report of the Committee, consisting of Dr. A. RUSSEL WALLACE (*Chairman*), Dr. JAMES CLARK (*Secretary*), Dr. G. J. ROMANES, Professor S. J. HICKSON, Professor E. A. SCHÄFER, *and* Dr. J. N. LANGLEY. (*Drawn up by the Secretary*).

THE members of this Committee wish to express their deep sense of the irreparable loss they have sustained in the death of Dr. Romanes, whose previous experience in this difficult field of inquiry rendered his judgment and advice invaluable.

During the past year the efforts of the Committee have been mainly directed to collecting facts and statistics relating to Telegony. In this they have received considerable assistance from the principal agricultural clubs in the country, and have been offered assistance by several societies in France, Switzerland, Germany, and America. Twenty-five preliminary reports have also been received from veterinary surgeons in Scotland and the North of England. In all over 900 letters and reports have been received. The majority, however, are too vague to be of any service, and many correspondents send generalisations 'based on personal observation and experience,' instead of recording facts. In the description of actual cases, too, the data supplied are generally too meagre. On account of the difficulty of obtaining reliable and sufficient data, the Committee consider it advisable to defer the publication of the collected facts until the important points connected with each can be verified or corroborated.

An examination of the pedigree cattle and of the stud-books and prize-bred horses of Yorkshire is also in progress, and will, it is hoped, be completed in the course of a few months.

The belief in Telegony among breeders and fanciers is very widely spread. The general consensus of opinion among our correspondents is that it frequently occurs in cats, occasionally in dogs and horses, rarely in birds, and almost never in cattle and sheep. The majority of the writers further insist that it is the first fertilisation only that has any effect upon subsequent offspring by a different male.

On account of the amount of work that still remains to be done, the Committee respectfully request that they may be re-appointed for another year.

Index Generum et Specierum Animalium.—Report of a Committee, consisting of Sir W. H. FLOWER (*Chairman*), Dr. P. L. SCLATER, Dr. H. WOODWARD, *and* Mr. W. L. SCLATER (*Secretary*).

THE proposed 'Index Generum et Specierum Animalium' is being compiled by Mr. C. Davies Sherborn, at the British Museum (Natural History).

The work on this index, which includes all animals, whether recent or fossil, has proceeded steadily since June 1890.

The manuscript now consists of 180,000 slips, representing 90,000 species and genera recorded in duplicate.

One set is sorted under genera for the convenience of students and the other set is kept under 'books,' so that it is possible at any moment to obtain a complete list of every genus and species described in a particular volume.

As the work proceeds much valuable information as to the dates of books is obtained, and this if sufficiently important is published: *e.g.*, Sowerby, 'Genera of Shells,' see 'Annals and Mag.,' April 1894; Schreber, 'Säugthiere,' see 'Proc. Zool. Soc.,' Jan. 1892; 'Encyclop. Méthodique,' see 'Proc. Zool. Soc.,' June 1893.

The small grant of 20*l.* made by the British Association in 1892 is the only financial help yet received towards the work, and has been expended upon paper. The Committee therefore ask for a new grant of 50*l.* toward a work which daily increases in importance and usefulness.

The Legislative Protection of Wild Birds' Eggs.—Report of the Committee, consisting of Sir JOHN LUBBOCK, Bart., *F.R.S.* (*Chairman*), Professor ALFRED NEWTON, *F.R.S.*, Rev. Canon TRISTRAM, *F.R.S.*, Mr. JOHN CORDEAUX, Mr. W. H. HUDSON, Mr. HOWARD SAUNDERS, Mr. THOMAS H. THOMAS, Dr. C. T. VACHELL, *and* Mr. H. E. DRESSER (*Secretary*). (*Drawn up by the Secretary*).

YOUR Committee beg leave to report that in the early portion of the present Parliamentary Session a fresh Bill to amend the Wild Birds Protection Act, 1880, was brought into the House of Commons by Sir Herbert Maxwell, Bart., M.P., and others, which Bill was on April 3 ordered by the House to be printed.

Your Committee had already been in communication with Sir Herbert Maxwell on the subject, and it was arranged to hold a meeting to discuss the clauses of this Bill, and a meeting was accordingly held on April 6, at which Sir Herbert Maxwell attended. The present Bill differs from that brought in by Sir Herbert Maxwell last Session (1893), in prohibiting the taking of the eggs of any specified kind within the limits of the country, or part or parts thereof, or else the taking of the eggs of any species within a certain stated area; it being left in the hands of the County Council to adopt either alternative. After some discussion it was decided by your Committee to approve the draft Bill as prepared by Sir Herbert Maxwell. This Bill has since passed through both Houses with but slight opposition, and has now come into force.

Migration of Birds.—Interim Report of a Committee, consisting of Professor A. NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Messrs. R. M. BARRINGTON, J. A. HARVIE-BROWN, W. EAGLE CLARKE, *and the* Rev. E. P. KNUBLEY, *appointed for the purpose of making a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels.*

THE Committee have to report that the systematic tabulation of the various items in the schedules has at length been completed by one of their number—Mr. W. Eagle Clarke—and that they are now prepared to approach the subject of the final report, which it is hoped will be ready for presentation at the meeting of the Association in 1895 or, at the latest, at the meeting in 1896.

The Committee trust that the Association will reappoint them as before.

The Climatological and Hydrographical Conditions of Tropical Africa.—Third Report of a Committee consisting of Mr. E. G. RAVENSTEIN (*Chairman*), Mr. BALDWIN LATHAM, Mr. G. J. SYMONS, *and* Dr. H. R. MILL (*Secretary*). (*Drawn up by* Mr. E. G. RAVENSTEIN.)

YOUR Committee, up to the end of July last, had issued five sets of meteorological instruments at a cost, including forms, carriage, &c., exceeding 100*l.* The first of these sets was entrusted to Mr. J. W. Moir (British Central Africa), the second to Mr. Buchanan (British Central Africa), the third to Captain Gallwey (Warri, Benin), the fourth to the Rev. C. Bonzon (Lambarene on the Ogowe), and the fifth to the Rev. R. Glennie (Bolobo, Congo). A sixth set is kept in reserve for British East Africa.

Two of these sets, namely, those in the hands of Mr. Buchanan and Mr. Glennie, include Fortin barometers, whilst that granted to Captain Gallwey includes a black bulb thermometer.

Observations up to the latest possible date have been received from Mr. Glennie, Mr. Bonzon, and Dr. Roth as representing Captain Gallwey.

Instructions have been issued to the officials of the Royal Niger Company to make their observations in future in accordance with the rules laid down by your Committee, and the like step is contemplated by the British East Africa Company.

Summaries of meteorological returns are appended to this report. Your Committee are quite aware that these observations are not in every instance as complete and trustworthy as could be desired. In some cases the hours of observation are ill chosen (a very common occurrence), in others the instruments are defective or the corrections to be applied to the readings are unknown. If they are published notwithstanding, it is done because they refer to localities concerning which nothing or very little is known at the present time.

Quite a number of meteorological records offered to the Committee for publication have had to be rejected as being on the face of them utterly untrustworthy. It seems a pity that so much time and labour should have been wasted upon recording observations which with a little forethought and caution might have furnished important information on the climate of Tropical Africa.

The grant of 5*l.* made to the Committee last year was not claimed.

Bolobo, Congo.* *Lat.* 2° 10′ *S.*, *Long.* 16° 13′ *E.*, 1080 *feet.* *Observer: Rev. Robert Glennie, Baptist Missionary Society.

Month	Pressure of Atmosphere: Means				Temp.: Extremes		Mean Temperature (Shade)						Daily Range	Mean Temp. in the Sun			Relative Humidity			Mean Temp. Wet Bulb			Rain		
	7 A.M.	2 P.M.	9 P.M.	Mean	Min.	Max.	7 A.M.	2 P.M.	9 P.M.	Max.	Min.	Mean		7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	7 A.M.	2 P.M.	9 P.M.	Amount	Days	Heaviest Fall
1891					°	°	°	°	°	°	°	°	°	°	°	°	p. c.	p. c.	p. c.	°	°	°	In.		In.
January	28·854	28·733	28·779	28·789	—	96·1	73·8	83·6	76·1	85·6	—	77·4	—	77·8	102·5	76·7	91	74	84	72·0	77·2	72·6	5·24	7	2·01
February	28·836	28·683	28·778	28·761	—	91·0	74·2	83·9	76·4	85·7	—	77·7	—	76·7	103·6	77·4	90	73	86	72·3	77·0	73·3	6·78	10	2·34
March	28·893	28·792	28·824	28·836	68·0	93·6	75·2	85·5	76·0	87·2	71·9	78·2	15·3	80·0	96·0	76·3	87	70	86	72·4	78·0	73·0	5·20	7	2·93
April	28·865	28·747	28·830	28·814	71·0	89·8	74·6	85·1	75·9	86·0	71·8	77·9	14·2	77·0	103·5	76·4	80	68	88	72·4	77·0	73·3	9·56	13	2·30
May	28·853	28·777	28·834	28·821	70·0	96·6	75·2	81·4	76·7	86·6	72·4	78·2	14·2	78·0	102·4	76·2	90	70	87	73·1	77·0	74·0	4·36	10	1·53
June	28·873	28·793	28·834	28·833	69·0	89·9	73·9	86·2	77·4	86·8	72·3	78·7	14·5	78·3	105·9	77·9	87	60	82	71·1	75·7	73·5	·04	1	·04
July	28·911	28·826	28·880	28·872	68·0	88·1	72·2	84·5	76·7	85·1	71·0	77·5	14·1	74·5	103·3	77·5	82	57	79	68·6	73·6	72·2	·04	1	·04
August	28·929	28·802	28·876	28·869	67·3	98·6	72·4	85·0	77·2	86·7	71·2	77·9	15·5	76·6	107·8	78·0	80	57	78	68·3	74·1	72·8	1·20	5	0·68
September	28·886	28·803	28·856	28·848	68·4	91·4	74·6	86·0	76·7	87·8	73·0	78·5	14·8	78·1	104·2	78·0	83	56	82	71·1	74·5	72·8	2·66	3	0·15
October	28·827	28·734	28·797	28·786	68·0	94·2	76·0	85·1	76·3	88·0	72·0	78·4	16·0	78·5	102·3	77·3	84	63	85	72·5	75·7	73·1	7·34	12	3·21
November	28·844	28·750	28·808	28·801	68·0	92·6	75·2	83·9	75·3	83·1	72·0	77·4	14·1	78·7	99·2	76·0	80	66	89	72·9	75·3	72·9	7·60	9	2·81
December	28·835	28·742	28·796	28·791	67·1	94·6	73·3	83·9	75·5	85·9	72·0	77·2	13·9	76·7	97·7	76·4	91	68	89	72·1	75·8	73·1	13·31	12	2·13
Year	28·867	28·765	28·824	28·818	67·1	96·6	74·4	84·6	76·3	86·5	—	77·9	—	77·6	102·1	77·0	86	65	85	71·5	75·9	73·0	63·93	90	3·21
1892																									
January	28·822	28·740	28·785	28·782	67·2	91·6	75·6	85·5	76·8	86·8	73·4	78·7	13·4	77·9	92·2	77·4	80	67	88	73·3	77·3	71·3	4·74	8	1·65
February	28·787	28·698	28·738	28·741	68·8	95·3	75·0	87·5	78·4	90·1	73·3	79·8	16·8	77·4	104·1	79·2	88	59	81	72·6	77·1	74·3	2·67	6	0·75
March	28·813	28·679	28·722	28·738	69·2	92·3	76·4	88·4	77·2	91·0	72·5	79·8	18·5	79·0	106·6	78·1	88	64	84	73·8	78·9	73·8	2·83	8	1·90
April	28·791	28·695	28·754	28·747	68·0	94·6	76·7	87·1	76·1	91·0	72·6	79·0	18·4	80·4	104·5	76·2	83	67	84	73·7	78·7	72·6	2·20	8	0·77
May	28·055	28·795	28·820	28·820	67·2	92·6	74·3	84·1	75·8	86·7	71·3	77·5	15·4	76·9	100·1	77·4	90	66	83	72·3	75·7	72·9	5·51	10	1·36
June	28·870	28·832	28·819	28·850	68·0	83·9	73·0	84·1	76·5	85·2	70·9	77·5	14·3	75·1	101·3	81·0	85	64	81	69·9	75·2	73·0	1·12	2	1·07
1893																									
October	28·829	28·730	28·789	28·783	67·0	91·1	73·4	82·7	74·1	85·8	70·9	76·1	14·9	—	—	—	90	68	88	71·3	75·0	71·7	8·49	12	3·53
November	28·837	28·743	28·823	28·801	67·4	90·6	73·4	82·2	74·7	84·6	70·6	76·2	14·0	—	—	—	87	72	88	71·7	75·5	72·2	9·05	14	2·00
December	28·805	23·701	28·759	28·755	66·9	88·7	73·2	81·4	74·3	83·9	70·0	75·8	13·9	—	—	—	93	73	89	71·8	75·1	72·1	9·96	18	1·88
Year	28·855	28·758	28·815	28·809	66·9	96·6	74·2	84·8	76·3	86·5	71·9	78·8	14·6	76·9	102·3	77·3	87	65	85	—	—	—	57·70	92	3·53

BOLOBO (Notes).

The station occupies the top of a slope on the left bank of the Congo River. The observatory is 350 feet from the river, 25 feet from the nearest house, and 20 feet from any vegetation. The screen is double-louvred, and the instruments are 4 feet 6 inches from the ground. Trees (forest) are to the north and east of the station, and this, combined with the draught of the river, prevents trustworthy observations of the direction of the wind being taken.

Since October 1893 Mr. Glennie is in possession of instruments furnished him by your Committee. On his return to Bolobo he compared these instruments with those in use before, and the instrumental errors then ascertained have been allowed for. This, however, does not apply to the barometrical observations and those made in the sun.

The pressure has been reduced to 32° F. and corrected for gravity. The mean temperatures have been deduced from ¼ (7.2.9.9.). The minimum temperatures observed in January and February 1891 were untrustworthy.

Combining all observations, we have the following results: Pressure highest in July, 28·872; lowest in February, 28·751; mean, 28·809. Mean temperature, 78°·8; annual range, only 2°·5 (December 76°·5, March 79°). Daily range, January 12°·8, March 16°·9, mean 14°·6. Relative humidity, 80 per cent. (in July and August 73 per cent., in December 85 per cent.). Rainfall nearly 58 inches; heaviest from October to December.

Kipo Hill, Niger. *Lat.* 8° 48′ *N.*, *Long.* 6° 25′ *E.*

Month	Temperature: Extremes recorded between 6 A.M. and 9 P.M.		Mean Temperature		
	Max.	Min.	9 A.M.	9 P.M.	Mean
1881	°	°	°	°	°
April	96	76	84	85	84·5
May	92	74	81	83	82
June	88	74	79	81	80
July	86	74	78	79	78·5

The observations were made by Rev. C. Paul, a native missionary, who had his thermometer given him by the late E. R. Flegel. The thermometer was read at three-hourly intervals between 6 A.M. and 9 P.M. Instrumental error not known.

Warri (*Benin*). *Lat.* 5° 31′ *N.*, *Long.* 5° 51′ *E.*, 10 *feet.*

Month	Temperature: Extremes		Temperature: Means			Daily Range	Black Bulb in Sun (Mean of Max.)	Rain		
			Max.	Min.	Mean			Amount	Days	Heaviest Fall
1891	°	°	°	°	°	°	°	In.	—	In.
November . .	83	72	84·3	77·4	81·8	6·9	—	—	—	—
December . .	89	72	86·0	77·0	81·5	9·0	—	—	—	—
1892										
January . .	89	76	86·2	78·5	82·3	7·7	—	—	—	—
February . .	87	74	85·5	79·2	82·3	6·3	—	—	—	—
March . . .	88	76	85·4	80·5	82·9	4·9	—	—	—	—
April . . .	86	73	84·0	77·6	80·8	6·4	—	—	—	—
May . . .	86	72	82·5	77·6	80·1	4·9	—	—	—	—
1893										
June . . .	92	69	81·0	73·3	77·1	7·7	141·1	14·96	23	3·54
July . . .	80	69	81·1	71·1	76·1	10·0	131·0	19·05	28	2·60
August . .	90	71	85·0	71·6	78·3	13·4	141·0	20·08	27	4·10
September . .	89	68	84·6	69·1	76·8	15·5	140·0	18·75	28	2·30
October . .	94	68	88·3	70·3	79·3	18·0	150·0	16·72	22	2·00
November . .	99	69	93·3	72·1	82·7	21·2	158·3	4·30	10	1·00
December . .	96	70	93·2	72·2	82·7	21·0	150·9	8·93	7	4·30
Year 1892–93 .	99	68	85·8	74·4	80·1	—	—	—	—	—

The observations were made by Captain H. L. Gallwey (November 1891 to May 1892), C. E. Harrison and H. E. Golley (June 1893), and Felix Roth, M.R.C.S. (July to December 1893). The observations since June 1893 have been corrected for instrumental errors. The earlier observations seem to be deserving of little confidence.

Namirembe, N. of Mengo, Uganda. Lat. 0° 18′ N., Long. 32° 34′ E., 4,000 ft.

(Communicated by G. F. Scott Elliott.)

Month	Pressure of Atmosphere. Aneroid, 8.15 A.M.	Temperature Extremes		Temperature : Means			Daily Range	Rain		Greatest Fall
		Max.	Min.	Max.	Min.	Mean		Amount	Days	
1893	In.	°	°	°	°	°	°	In.		In.
March (18 31).	26·15	81·7	55·0	75·0	57·7	66·2	17·3	2·88	10	0·98
April . .	26·14	82·2	52·1	76·3	57·7	67·0	18·6	9·03	23	1·45
May . .	26·15	82·6	55·3	75·1	58·0	66·5	17·1	3·96	21	1·15
June . .	26·16	78·8	55·2	75·2	57·8	66·5	17·4	2·40	10	1·68
July . .	26·16	79·3	54·7	74·0	55·5	64·7	18·5	1·02	10	0·30
August . .	26 20	82·0	55·0	78·1	56·9	67·5	21·2	0·67	5	0·43
September .	26·16	79·9	52·3	76·0	55·7	65·8	20·3	5·03	25	1·37
October . .	26·15	80·9	54·2	77·1	56·8	67·0	20·3	4·77	17	1·09
November .	26·20	82·9	55·9	76·8	58·1	67·4	18·7	2·71	13	0 82
December .	26·18	84·9	55·8	80·8	58·8	69·7	21·8	2·13	8	0·81
1894										
January . .	26·14	85·8	53·2	81·7	58·1	69·6	23·1	0·36	5	0·21
11 Months .	26·16	85·8	52·1	76·9	57·4	67·1	19·5	34·96	147	1·68

Observer: Rev. E. Millar, C.M.S., whose journal was communicated by Mr. G. F. Scott Elliott. Instrumental errors unknown; the observations are given as recorded. On February 3 the station was burnt down, and all the instruments were lost.

Fort Salisbury. Lat. 17° 50′ S., Long. 31° 4′ E., 5,050 feet.

Month	Pressure	Temperature: Extremes		Temperature : Means			Daily Range	Rain		Prevailing Wind
		Max.	Min.	Max.	Min.	Mean		Amount	Days	
1891	In.	°	°	°	°	°	°	In.		
February .	25·321	87	56	79	60	69·5	19	11·98	19	E.N.E.
March .	25·346	85	53	79	59	69·0	20	12·73	14	E.N.E.
April .	25·413	86	46	79	52	65·5	27	0·71	3	E.S.E.
May . .	25·439	84	41	77	49	63·0	28	0·36	2	E.N.E.
June . .	25·444	81	37	75	43	59·0	32	—	—	N.E.
July . .	25·494	77	40	71	45	58·0	26	—	—	E.S.E.
August .	25·472	86	39	77	47	62·0	30	—	—	N.E.
September	25·433	92	41	84	52	68·0	32	—	—	E.N.E.
October .	25·393	93	41	82	55	68·5	27	0·81	4	E.
November	25·389	91	52	82	59	70·5	23	3·51	7	E.
December .	25·344	88	52	79	60	69·5	19	6·89	16	E.N.E.
1892										
January .	25·301	85	58	79	62	70·5	17	7·20	17	N.E.
February .	25·281	89	48	80	57	68·5	23	1·51	9	E.
March .	25·339	89	53	84	57	70·5	27	1·90	9	E.N.E.
April .	25·383	87	42	79	54	66·5	25	1·67	5	E.
May . .	25·445	82	36	77	47	62·0	30	—	—	E.S.E.
June . .	25·428	80	34	74	41	57·5	33	—	—	E.
July . .	25·466	79	35	73	41	57·0	32	—	—	E.
Year .	25·398	93	34	78·9	53·5	66·2	26	33·84	75	E., E.N.E.

The observations were made by Major F. W. Forbes, and communicated by Mr. F. C. Selous. They are published as received. The means for the year are deduced from all the observations made.

Dr. Livingstone's Rainfall Observations in Central Africa, 1866–71. *Communicated by the Rev. Horace Waller.*

Month	Rainfall			Prevailing Wind	Remarks
	Days measured	In.	Days not measured		
October	1	·13	1	—	Dr. Livingstone's Journal begins at Mapuyo (14° S., 33° 30′ E.) on October 25. In December he reached Chitembo, on March 12, 1867, Chiwe's, and in April the southern end of Tanganyika. The first rain fell, on October 26, at Mapuyo—merely a few drops.
November	8	3·42	1	—	
December	12	6·67	2	—	
January	21	11·55	1	—	In January Livingstone notices that the rain clouds on the south side of the range separating the Loangwa from the Chambeze came generally from the west, whilst those on the north side came from the N.N.E. and E.
February	24	11·65	—	—	
March	10	6·89	1	—	
April	4	2·08	—	—	
1866–67	80	42·39	6	—	
October	6	1·10	4	—	October was spent at Karungu (8° 15′ S., 30° 15′ E.) and neighbourhood. On November 21 Dr. Livingstone arrived at Kazembe's; in January, 1868, he reached Katwakwa, near the N.E. extremity of the Mweru, and spent the remainder of the season there and in the neighbourhood.
November	16	8·19	—	—	
December	15	9·18	—	—	
January	11	11·19	1	—	
February	14	8·71	—	E.	
March	13	10·85	4	W. & E.	The rains ceased April 21, but in May there was a thunderstorm.
April	10	8·98	--	E.	
May	1	·09	—	E.	
1867–68	86	53·29	9	—	
August	1	1·80	—	S.E.	On August 7 Dr. Livingstone left Kisinga (10° 30′ S., 29° E.) and, travelling northward, was back at Kabwakwa in October. He left that place in December, reached Lake Tanganyika in February 1869, and Ujiji, where he remained, on March 14, 1869.
September	3	·95	1	S.E.	
October	6	·58	6	S.E.	
November	14	4·59	2	S.E.	
December	17	5·98	3	N.W.	
Carried forward	41	13·90	12	--	

Month	Rainfall			Prevailing Wind	Remarks
	Days measured	In.	Days not measured		
Brought forward—	41	13·90	12	—	
January	3	2·34	—	—	The 'Hot Season' (Kaskas) began on August 29. On the 29th there was a thunderstorm.
February	4	2·66	—	—	
March	5	4·69	--	—	Hail fell on October 18.
April	12	8·33	1	—	During the S.E. winds, September to November, the upper strata of clouds were observed to drift to the S.W.
May	14	8·50	—	S.E.	
1868–69	79	40·42	13	—	
September	2	·54	3	S.E.	Most of the observations were made at Bambarre and Mahomela in the Manyema country.
October	11	6·28	2	S.E. to N.E.	
November	11	9·09	1	S.E.	
December	13	7·80	2	S.E.	
January	12	4·99	—	S.E.	Hail fell on September 11 and November 27.
February	11	4·48	—	N.W.	
March	11	3·05	—	N.W.	
April	16	11·32	—	S.W. & S.E.	
May	9	7·78	—	do.	
June	5	·47	—	variab'e	
1869–70	101	55·82	8	—	
September	3	·90	--	E.	The rainy season was spent in the Manyema country, principally at Bambarre, Mahomela (February 25 to March 2) and Nyangwe (March 29 to end of June).
October	8	5·19	5	E.	
November	14	4·37	—	E.	
December	14	10·02	—	E.	
January	15	12·03	--	N.W., E.	The first thunder was heard at Bambarre on August 25, but no rain fell.
February	8	4·50	2	N.W., E.	
March	8	11·21	1	S.E.	Hail fell on October 29, December 11, and January 4.
April	10	5·25	—	S.E.	
May	6	5·00	—	N.W. by N. to S.E.	
June	2	1·51	1	—	
1870–71	88	[illegible]	9	--	

Ribe. Lat. 3° 55′ *S., Long.* 39° 40′ *E.,* 500 *feet.*

Month	Pressure		Temp. Extremes		Temperature : Means				Rain amnt.	Cloud (1-10)	Prev. Wind
	9 A.M.	9 P.M.			6 A.M.	3 P.M.	9 P.M.	Mean			
1876	In.	In.	°	°	°	°	°	°	In.		
May	29·579	29·521	70	82	74·2	—	75·4	—	5·14	—	—
June	29·610	29·381	69	80	71·9	77·9	72·7	74·2	3·34	—	—
July	29·614	29·569	69	80	70·5	76·0	71·8	72·8	5·12	—	—
August	29·587	29·555	69	81	70·3	77·1	71·8	73·1	2·25	—	—
September	29·587	29·540	69	84	71·4	79·5	72·2	74·4	2·20	5·0	S.E.
October	29·538	29·485	72	86	75·4	83·4	76·7	78·5	1·02	5·5	E.b.S.
November	29·467	29·414	75	91	77·4	86·4	79·6	81·1	0·71	5·2	E.b.S.
December	29·464	29·421	74	91	77·6	86·6	80·8	81·6	3·23	—	—
1877											
January	29·454	29·411	75	91	78·0	88·6	80·0	82·2	1·53	6·0	S.E.
February	29·465	29·415	76	92	78·2	88·6	80·4	82·4	0·00	4·0	E.S.E.
March	29·435	29·388	76	82	79·3	87·0	81·3	82·5	4·44	4·3	E.
April	29·437	29·394	76	90	78·0	85·1	79·6	80·9	5·25	5·2	S.E.
May	29·330	29·495	70	88	74·9	82·1	76·4	77·8	11·46	6·0	S.E.
June	29·635	29·602	72	82	73·3	77·2	74·2	74·9	6·45	6·0	S.
July	29·613	29·599	71	82	72·7	78·4	73·4	74·8	4·12	5·5	S.W.
August	29·611	29·585	71	82	72·5	78·4	73·7	74·9	8·54	5·0	S.E.
September	29·540	29·480	73	84	75·5	80·3	75·4	77·1	11·63	6·5	S.E.
October	29·523	29·490	72	83	74·5	80·4	75·8	76·9	14·50	7·0	E.
November	29·449	29·422	75	87	77·0	84·5	79·1	80·2	20·00	5·0	E.
December	29·419	29·409	76	89	78·7	86·0	80·2	81·6	3·55	4·0	NNE.
Year 1877	29·509	29·474	70	92	76·0	83·0	77·5	78·8	91·47	5·4	—

The observations were made by the Rev. Thomas Wakefield.

They were not made regularly, but are sufficiently numerous to enable us to deduce approximate means.

The *rain-water*, during Mr. Wakefield's occasional absences, was allowed to accumulate, and then measured. In 1877 the rainfall at Mombasa was 91·06 inches, almost the same as at the neighbouring Ribe. This, how ver, was an exceptionally wet year, the average not exceeding 51 inches.

The pressure has been reduced to 32° and corrected for gravity. The instrumental errors are not known.

Mochi, Kilimanjaro. Lat. 3° 18′ *S., Long.* 37° 23′ *E.,* 5,000 *feet.*
Sagala, Taita. Lat. 3° 32′ *S., Long.* 38° 35′ *E.,* 3,300 *feet.*

Month	Temp. Extremes		Temperature: Means			Daily Range	Rain amnt.
			Max.	Min.	Means		
MOCHI	°	°	°	°	°	°	In.
January	81	55	77	59	68	18	3·15
February	82	56	79	59	69	20	little
March	81	57	75	59	67	16	do.
April	77	56	72	60	66	12	heavy
May	74	54	69	57	63	12	do.
June	70	52	66	54	60	12	little
July	75	52	66	54	60	12	do.
August	75	50	69	54	61	14	0·63
September	80	53	72	56	64	16	1·95
October	80	54	77	57	67	20	0·79
November	82	80	75	59	67	16	5·01
December	80	58	76	62	69	14	9·08
Year	82	50	73	57	65	16	--
SAGALA							
January	—	—	—	—	—	—	0·50
February	95	61	86	63	74	23	1·90
March	97	59	89	64	77	25	3·00
April	87	58	79	61	70	18	5·90
May	85	59	80	61	70	19	1·20
June	80	57	77	58	68	19	6·10
July	80	54	76	58	67	18	—
August	85	55	77	56	67	21	—
September	93	55	83	57	70	26	—
October	92	57	84	59	71	25	—
November	96	59	88	62	75	26	—
Year	96	54	83	61	72	21	—

The observations at Mochi C. Miss. Station were taken by the Rev. W. Morris and Rev. E. A. Fitch, those at Sagala by the Rev. W. Morris and Mr. J. A. Wray. Instrumental errors not known.

The Exploration of Hadramout in Southern Arabia.—Report of the Committee, consisting of Mr. H. SEEBOHM (*Chairman*), Mr. J. THEODORE BENT (*Secretary*), Mr. E. G. RAVENSTEIN, Dr. J. G. GARSON, *and* Mr. G. W. BLOXAM. (*Drawn up by* Mr. BENT.)

OUR expedition left Aden on December 15, 1893, for Mokulla, the seaport from which we were to start inland for the Hadramout valley. The coast-line of this part of Arabia is peculiarly harbourless, and the only ports for the Hadramout valley are Mokulla and Sheher, the former being only available during the north-east monsoons, and the latter being merely an open roadstead. Sheher was until late years the most flourishing of the two places, but the transfer of the suzerainty over these places to the Al Kaiti family has resulted in Mokulla becoming by far the most thriving of the two, and Sheher is gradually falling into ruins.

Before describing the interior it will be well to explain the conditions of political affairs in the Hadramout and the origin of the Al Kaiti family which rules there. At present this is the most powerful family in the district, and is reputed to be the richest in Arabia.

About five generations ago the Sayyids of the Aboubekir family, at that time the chief Arab family in the Hadramout, who claimed descent from the first of the Caliphs, were at variance with the Bedouin tribes, and in their extremity they invited assistance from the chiefs of the Yafi tribe, who inhabit the Yafi district, to the north-east of Aden. To this request the Al Kaiti family responded by sending assistance to the Sayyids of the Hadramout, and putting down the troublesome Bedouin tribes, and establishing a fair amount of peace and prosperity in the country, though even to this day the Bedouins of the mountains are ever ready to swoop down and harass the more peaceful inhabitants of the towns. At the same time the Al Kaiti family established themselves in the Hadramout, and for the last four generations have been steadily adding to the power thus acquired. Mokulla, Sheher, Shibam, Haura, Hagarein, al belong to them, and they are continually increasing by purchase the area of their influence in the collateral valleys, building substantial palaces and establishing one of the most powerful dynasties in this much divided country. They get all their money from India and the Straits Settlements, for it has been the custom of the Hadrami to leave their own somewhat sterile country to seek their fortunes abroad. The Nizam of Hyderabad has an Arab regiment composed entirely of Hadrami, and the Sultan Nawasjung, the present head of the Al Kaiti family, is its general: he lives in India, and governs his Arabian possessions by deputy. His son Ghalib rules in Sheher, his nephew Manassah rules in Mokulla, and his nephew Salah rules in Shibam, and the governors of the other towns are mostly connections of this family. The power and wealth of this family are almost the only guarantee for peace and prosperity in an otherwise lawless country.

The configuration of the country is interesting and very peculiar; the coast-line all the way from Mokulla to Saihut is hopelessly arid and unproductive, except where hot springs come out of the ground. That at Ghail ba Wazir, about twelve miles from Sheher, is utilised for the cultivation of tobacco, palms, and fodder; that at Al Hami is exceedingly hot, so hot that when it rises the hand can hardly bear it; that at Dis also fertilises a considerable area, and there are several others. Beyond these natural streams, or *ghails* as they are called, the coast-line is both waterless and featureless, and it is very narrow : in most parts the line of mountains begins to rise about six miles from the coast, and continues an abrupt and almost unbroken line all along the coast. Several caravan roads penetrate into the interior up the short valleys, but in every case there is a very steep ascent, exceedingly arduous for camels and beasts of burden. At an elevation of 5,000 feet there is a plateau extending on all sides, as far as the eye can reach, divided by nature into two storeys, the upper one being about eighty feet higher than the lower, and representing what is left of a higher surface gradually disappearing in the course of ages. On the upper storey vegetation is entirely absent, and in many places the ground is covered with black basaltic stones scattered over the surface as if from a gigantic pepper-pot. In the gullies of this upper storey there are considerable traces of vegetation, and it is here that the myrrh trees and frankincense trees grew which once formed the wealth of this district. The subject of frankincense and myrrh is of course one of the most interesting in connection with the Hadramout, as this portion of Arabia was the one which supplied the ancient world with these precious drugs ; and when one considers how they were anciently used, both for private and religious purposes, one can readily understand the commercial importance of these commodities. Claudius Ptolemy gives us accurate information as to the caravan routes by which the drugs were conveyed to the Mediterranean from the country of the Hadramitæ, or Chatramitæ as the Greeks, from their inability to sound the initial H, called it. Pliny also affords us valuable information on the subject, as do also the Arabian geographers of the earlier centuries of our era. From personal observation I should say that the ancients held communication with the Hadramout almost entirely by the land caravan route, as there are absolutely no traces of antiquity to be found along the arid coast-line, whereas the interior valley and its collateral branches are very rich in remains of the ancient Himyaritic civilisation. Evidently the trees which produced these drugs grew on the plateau. Myrrh trees are still very common on it, and every year Africans come over from Somaliland for the purpose of collecting the sap. During our wanderings we only once came across a specimen of the frankincense tree : it has evidently almost entirely disappeared from this locality, but is to be still found in abundance, I am told, further east, in the country of the Mahri tribe.

It is highly probable that the systematic destruction of the timber on this plateau during the course of countless ages has much to say to the present deplorable condition of the Hadramout and its collateral valleys. These are all being silted up by sand, which invades them from the central desert on the north and from the plateau on the south. This sand in many instances is forty feet deep, and entirely covers the running waters which for the purposes of cultivation have to be brought up by wells and led to the land intended for cultivation by an elaborate system of irrigation. There are very few running streams in this district, and every year we were told they are becoming fewer, and will undoubtedly very soon disappear altogether. The inhabitants of the Hadramout have a hard struggle to maintain against this invasion of their country by a natural catastrophe, and were it not for the custom of the inhabitants of going abroad to seek their fortunes, there is no doubt that long ago the country would have been abandoned, and the struggle for existence given up. The strong fanaticism of the inhabitants and their belief in the sacredness of their country have been another very important factor in perpetuating its existence. Every man who leaves the Hadramout in search of fortune hopes to return and die in the odour of sanctity. No woman ever leaves the country, and there are cases on record of a wife being separated from her husband for forty years. On their return the wanderers relapse into the same condition of fanaticism and hatred of all external influence which has obtained in this country from time immemorial, and all they have gained is money with which to continue to live in their own valley, and erect the castles and palaces with which the whole line of the Hadramout is thickly studded.

The plateau when reached extends, as I have said, to an apparently unlimited extent in every direction; after one day's journey, however, it will be seen that valleys running northwards are cut out of this flat surface like slices out of a cake. The principal valleys which run into the big central valley from the south are the Wadi Al Isa, Al Eyn, Dowan, Rachy, Adym, and Ben Ali; there are many others which we had not the time or opportunity to visit. The chief peculiarity of these valleys is that they descend very rapidly, and are at their head very nearly as deep as during the rest of their course. They seem as if they had formed part of a great inland fiord, from which the sea retired at some remote period, leaving the successive marks of many strands on the sandstone and limestone walls which shut in these valleys. Everywhere the descent into them is rapid and difficult, and no place I have ever seen in the world can possibly be more shut off and hemmed in by natural features as the broad main valley known as the Hadramout and its collateral branches. The old Arabian story of Sinbad descending into a deep valley on the back of a roc must have originated in some such country as this. It is remarkable how the camels contrive to get to and fro, and frequent accidents to the animals take place during the ascent and descent from the plateau. As seen from above, the aspect of these long narrow valleys is exceedingly curious; the walls of rocks are almost precipitous, about 1,000 feet in height. In many places the valleys are not a mile wide, and present one long unbroken line of villages, each with its palm grove, its cultivated land, its big castles and houses, and its surrounding hovels for the lower classes. Even the Bedouins have big houses here and settled abodes when on a journey or pasturing their flocks; they have no tents, and are little better than naked savages. But when they return home to their valley we find them living in large commodious houses several storeys in height, with the antlers of antelopes decorating them outside, and though only built of sun-dried bricks their architecture reminds one of the mediæval towns on the Rhine. In fact, if one could substitute a flat surface of sand covering the river bed and place almost treeless mountains on either side one might well compare these valleys to those of Germany. The town of Hagarein is built on an isolated hill in the middle of the Wadi Kasr, with its walls and battlements, its turrets and machicolations: it looks at a distance exactly like one of the fortified mediæval towns of Europe.

In most cases the narrower valleys are the most fertile, the water supply is far better than it is in the main valley, for at the head of the main valley are the salt hills of the Shabwa district, from which, as in the days of Makrisi, the Bedouins bring caravans of salt: this impregnates the water of the main valley with strong alkaline deposits, and the water from the wells, especially in the centre of the valley, is very disagreeable. This, however, is not the case in the narrower valleys, and from the Wadi Adym, the Wadi Al Eyn and Dowan, come the best dates and the best honey, which form two of the principal productions of the country.

In many places the main valley of the Hadramout is very wide—even near Shibam it is three miles wide, and where it is entered by the collateral branches considerably more. We were only able to trace its course as far as Terim, but beyond that, as it slopes towards the sea of Saihut, I have reason to believe it assumes magnificent proportions, but owing to the hostility of the tribes in that direction we were unable to proceed, as we had wished, along the whole length of it; and even the Arabs, under the rule of the Al Kaiti family, are themselves ignorant of this route, always going down to the sea by the plateau roads, as the long valley road is unsafe for caravans.

Our investigations were principally confined to the main valley and its arteries. The Sultan of Shibam hospitably entertained us in his palace at Al Katan for three weeks, from which point we were able to visit a large number of the places of interest in the vicinity. At El Meshed we visited the ruins of a very large town at the mouth of the Wadi Dowan, and brought home several inscriptions therefrom. Also at two or three other spots near Shibam we got inscriptions; but the expedition which most repaid us was that up the Wadi Ser to the north of the main valley, by which we were able to determine the position of the great central desert at this point, and also, from inscriptions, one of the old caravan roads which led northwards from the frankinçense country. In this valley too we visited the Kabr Salah, one of the tombs held sacred by the Bedouins, and particularly watched over by them as distinct from the Arab shrines: it is a long tomb forty feet in length, and is one of many tombs popularly supposed by the Bedouins to belong to a race of giants which are to be found at several points in the Hadramout. There is no question about it that the Bedouins represent an older civilisation and practise an older cult than the Arabs in this district. The Sayyids and Sherifs of the Arab population look down on the Bedou, referring to them as heathen who only outwardly conform to the laws of Mohammedanism when absolutely compelled.

The inscriptions and archæological results of our Hadramout expedition are now in the hands of the great Himyaritic scholar, Dr. D. H. Müller, of Vienna, and I have confident hopes that he will be able to produce for us some interesting results.

The map of our expedition and a survey of the country which we traversed have been made by Imam Sherif, Khan Bahadar, who was sent out by the Indian Government. It is particularly valuable as being the first attempt at surveying anything beyond the coast-line in this part of Arabia, and I have hopes that he will accompany us again next year to continue this work.

There is a remarkable absence of mammalia in the Hadramout; we only saw a few gazelle and heard of the ibex as dwelling in the mountains near Siwun. The fact that we constantly saw the rotting carcasses of sheep proves the total absence of carnivorous beasts and birds, which is doubtless due to the lack of running water. There are also very few birds of any sort in the valley, though in the cultivation near Al Katan we saw quantities of swallows, evidently hibernating there. The naturalist sent out by Dr. Anderson, however, made an excellent collection of snakes, lizards, and other reptiles which abound in the rocky mountains. These are at present being arranged by Dr. Anderson, and a complete set will be presented to the Natural History Museum at South Kensington.

Owing to the fanaticism of the natives we were unfortunately unable to take any anthropometric observations; in fact, it would have been extremely dangerous to do so in the interior. I have hopes, however, another season to be able to do this at some of the coast towns, where the Bedouins from the interior go down in considerable numbers. They are very interesting as types of an early race, being very different from the Bedouins of Northern Arabia. They are short, thin, and wiry, with handsome, refined faces, aquiline noses, and thin lips, almost as dark as negroes in their skin, and with long black hair, which they tie up in a knot at the back of their heads. During our long stay at Al Katan we were able to collect many interesting points with regard to their manners and customs, but the same difficulty that prevented us from taking measurements also confronted us in trying to take photographs of this interesting type of humanity. They have a fixed objection to sitting for their portraits, and the few we took at haphazard do not give a very satisfactory idea of the type.

Mrs. Bent was, however, able to take an interesting series of views of the Hadramout valley, the palaces and buildings, &c., which give a good idea of the country.

The botanist (W. Lunt) who was sent out by the authorities of Kew made a collection of the flora of this district, which is rather meagre, but very interesting, as being the first collection brought from Arabia east of Aden. In it there are four new genera and thirty new species, which is remarkable, considering that the collection did not contain much over 200 varieties; and it has also established the fact that the flora of Arabia corresponds most closely to that of Abyssinia.

We purpose to return to Arabia during the coming winter, and, if possible, to enter at Muscat and make our way thence to the Hadramout, which will give us an opportunity of surveying the whole inhabitable line of country along the coast of South-eastern Arabia. We therefore hope for the reappointment of the Committee, with a grant of money.

Geographical, Meteorological, and Natural History Observations in South Georgia or other Antarctic Island.—Report of the Committee, consisting of Mr. CLEMENTS R. MARKHAM (*Chairman*), Dr. H. R. MILL (*Secretary*), Mr. J. Y. BUCHANAN, *and* Mr. H. O. FORBES.

THE Committee met on two occasions and considered the possibility of carrying out Mr. Bruce's plan for spending a year on South Georgia or other land within the Antarctic Circle. It was found to be possible to obtain a passage for Mr. Bruce either to South Georgia or possibly to the Antarctic land south of Australia; but no guarantee would be given by the Norwegian whalers and sealers making experimental voyages in these waters that they could return for him after a year. In the circumstances the Committee decided that it would be undesirable to encourage Mr. Bruce to run the risk of an expedition the return from which was so uncertain, and the sum of 50*l.* drawn by the Committee and held in readiness to add to Mr. Bruce's funds in case he should be able to make satisfactory arrangements will be repaid to the Treasurer.

The Committee desire to impress upon the Association the desirability of memorialising Government on the great scientific advances which will certainly follow a well-equipped expedition to the Antarctic regions. The success attending the recent voyages of Norwegian whaling and sealing vessels in the discovery of new lands of great interest is fresh evidence of the work which may be done in high southern latitudes by protected steamers.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Mr. S. BOURNE, Mr. G. GLADSTONE, Mr. J. HEYWOOD, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Professor N. STORY MASKELYNE, Sir H. E. ROSCOE, Sir R. TEMPLE, *and* Professor S. P. THOMPSON. (*Drawn up by* Dr. GLADSTONE.)

APPENDIX.—*Addition to Alternative Courses in Elementary Science* . . *page* 364

LAST year your Committee were able to report a rapid advance in the adoption of elementary science as a class subject in the day schools, and the great provision made for it in the New Code for evening continuation schools. This year they have only to report progress in the same direction.

The number of departments of schools in which the following class subjects were examined by Her Majesty's Inspector during the eight years 1882 to 1890, when English was obligatory, were as follows :—

Class Subjects.—Departments	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89	1889–90
English	18,363	19,080	19,431	19,608	19,917	20,041	20,153	20,304
Geography	12,823	12,775	12,336	12,055	12,035	12,058	12,171	12,367
Elementary Science . .	48	51	45	43	39	36	36	32

The numbers during the last three years, when managers and teachers have had full liberty of choice, have been as follows :—

Class Subjects.—Departments	1890–91	1891–92	1892–93
English	19,825	18,175	17,394
Geography	12,806	13,485	14,256
Elementary Science . . .	173	788	1,073

It will be noticed that during the former period, while the study of English Grammar increased with the natural increase of schools, the study of scientific subjects positively decreased; but since that time, while Grammar has rapidly declined, Geography, and especially Elementary Science, which was almost non-existent before, have rapidly increased.

The number of scholars examined in the scientific specific subjects during the eight years 1882–90 has been as follows :—

Specific Subjects.—Children	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89	1889–90
Algebra	26,547	24,787	25,347	25,393	25,103	26,448	27,465	30,035
Euclid and Mensuration . .	1,942	2,010	1,269	1,247	996	1,006	928	977
Mechanics, A	2,042	3,174	3,527	4,344	6,315	6,961	9,524	11,453
„ B	—	206	239	128	33	331	127	209
Animal Physiology . . .	22,759	22,857	20,869	18,523	17,338	16,940	15,893	15,842
Botany	3,280	2,604	2,415	1,992	1,589	1,598	1,944	1,830
Principles of Agriculture .	1,357	1,859	1,481	1,351	1,137	1,161	1,199	1,228
Chemistry . . .	1,188	1,047	1,095	1,158	1,488	1,808	1,531	2,007
Sound, Light, and Heat . .	630	1,253	1,231	1,334	1,158	978	1,076	1,183
Magnetism and Electricity .	3,643	3,244	2,864	2,951	2,250	1,977	1,669	2,293
Domestic Economy . . .	19,582	21,458	19,437	19,556	20,716	20,787	22,064	23,094
Total	82,965	84,499	79,774	78,477	78,122	79,985	83,420	90,151
Number of scholars in Standards V., VI., and VII.	286,355	325,205	352,860	393,289	432,097	472,770	490,590	495,164

The numbers during the last three years are :—

Specific Subjects.—Children	1890–91	1891–92	1892–93
Algebra	31,349	28,542	31,487
Euclid	870	927	1,279
Mensuration	1,489	2,802	3,762
Mechanics	15,559	18,000	20,023
Animal Physiology . . .	15,050	13,622	14,060
Botany	2,115	1,845	1,968
Principles of Agriculture . .	1,231	1,085	909
Chemistry	1,847	1,935	2,387
Sound, Light, and Heat . .	1,085	1,163	1,168
Magnetism and Electricity . .	2,554	2,338	2,181
Domestic Economy . . .	27,475	26,447	29,210
Total	100,624	98,706	108,434

It is interesting to see what have been the changes of popularity in the different subjects recorded above. The most striking change has been the rapid and continuous increase in the study of Mechanics of from 2,000 to 20,000 scholars. Animal Physiology, Botany, and the Principles of Agriculture show a steady decrease. The separation of Euclid and Mensuration has had a good effect upon the teaching of both, especially the latter. The physical sciences have fluctuated from time to time, but have never commanded any great amount of attention. Domestic Economy shows a considerable actual increase, but not in proportion to the number of girls in the higher standards.

Estimating the number of scholars in Standards V., VI., and VII. at 535,000, the percentage of the number examined in these specific subjects as compared with the number of children qualified to take them is 20·2 ; but it should be remembered that many of the children take more than one subject for examination. The following table gives the percentage for each year since 1882 :—

In 1882–83	. . . . . .	29·0 per cent.
„ 1883–84	. . . . .	26·0 „
„ 1884–85	. . . . .	22·6 „

In 1885–86	19·9 per cent.
„ 1886–87	18·1 „
„ 1887–88	16·9 „
„ 1888–89	17·0 „
„ 1889–90	18·4 „
„ 1890–91	20·2 „
„ 1891–92	19·7 „
„ 1892–93	20·2 „

The returns of the Education Department given above refer to the whole of England and Wales, and are for the school years ending with August 31. The statistics of the London School Board are brought up to the year ending with Lady Day, 1894. They also illustrate the great advance that has been made in the teaching of Elementary Science as a class subject, and they give the number of children as well as the number of departments.

Years	Departments	Children
1890–91	11	2,293
1891–92	113	26,674
1892–93	156	40,208
1893–94	183	49,367

The alterations in the New Code bearing upon instruction in Science are as follows:—

1. The addition of Domestic Economy (for girls) to the list of class subjects. Hitherto it has only been recognised as a specific subject, which limited the instruction to the higher standards. If taken as a class subject, it will, of course, have to be taught throughout the school.

2. The addition of Hygiene to the list of specific subjects.

3. The inclusion of Horticulture in the Schedule of Alternative Courses in Elementary Science. This is practically the same as Horticulture treated as a specific subject, but spread over the seven standards.

4. The insertion in the same Schedule of an entirely new course, called 'Experimental Arithmetic, Physics and Chemistry.' This is so great a departure from ordinary methods, and is likely to effect so decided an improvement in the mode of teaching, that it is thought desirable to set out the programme in full detail. It will be found in the Appendix to this Report. It follows somewhat on the lines of the Elementary course in Practical Science which appeared in the Evening School Code of last year, and to which your Committee drew particular attention in the Report presented at the Nottingham meeting. This will go far to realise the hope then expressed that these improved methods of instruction may be largely adopted in the day schools.

The changes in the Code with regard to the instruction of pupil teachers in science subjects are in an opposite direction. The whole of the provision hitherto made for the encouragement of the study of science by the pupil teachers has been swept away. But it is understood there is an intention to put in its place an obligatory course of Primary Science, which may form the basis for any further special science which may be taken optionally. If this idea is carried out, it will place Natural Science for the first time in its proper place in the curriculum. In the meantime, however, no marks can be obtained at the Queen's Scholarship examination for passes in any science subject at the Science and Art Department examination, or for the holding of University Extension certificates in science.

For several years past the Instructions to Inspectors have contained a clause stating that, among the things provided by a good school, may be 'an orderly collection of simple objects, geological and botanical specimens, examples of industrial processes or other apparatus, chiefly designed to illustrate the school lessons, and formed in part by the co-operation of the scholars themselves.' This year the Department have taken the further step of stipulating that 'a classified list of the objects and other articles of interest in the school museum should also be kept.' This will render the school museums more valuable instruments of education, and prevent them from degenerating into a mere miscellaneous assemblage of objects.

In regard to evening continuation schools, there is no alteration in the Code that calls for remark. But in the Revised Instructions to Her Majesty's Inspectors my Lords say: 'The subjects taught in the day school should be such as to form a solid foundation on which the higher studies of the evening may be built. The knowledge of the scientific principles which underlie the technique of the industries of the neighbourhood . . . is among the most important of such subjects. It might help to secure the continuity of school life if the day scholars were allowed occasionally to attend some of the more attractive evening lessons, such as travels illustrated by the optic lantern, or a science lecture illustrated by experiments.' Optic lanterns are now of so excellent a character that they can be used for illustrating lessons in the daytime without darkening the room. The London School Board has recently purchased a dozen with that view.

For the last four years there has been a clause in the Code stating that, 'in making up the minimum time constituting an attendance, there may be reckoned time occupied by instruction in science (amongst others), whether or not it is given in the school premises or by the ordinary teachers of the school, provided that special and appropriate provision, approved by the Inspector, is made for such instruction, and the times for giving it are entered in the approved time-table.' The London School Board have made several attempts to get leave from the Education Department to allow of occasional visits to such places as Kew Gardens, South Kensington Museum, &c., to be so counted. But although 'the Science and Art Department recognise attendance at such places, provided that the attendance is for not less than for one hour, that the visit is made for the purpose of the scholars receiving instruction, and that the scholars are instructed during the visit by the teacher of the class,' the Education Department still require the literal fulfilment of the above-mentioned clause, which is framed to meet the conditions of centre teaching, and not of visits to other institutions of an educational character. A recent deputation from the Manchester Art Museum on the subject of bringing picture galleries, public museums, &c., into requisition in teaching art and science was, however, very favourably received by Mr. Acland, and he promised increased facilities for this purpose in next year's Code. Your Committee trust, therefore, that, not only will the London School Board be allowed to make the use they propose of such institutions, but that the provision may be made general, so as to apply to all the schools in the provinces wherever the means exist of obtaining such practical instruction.

On January 6 last the Education Department issued a valuable circular (No. 332) on the subject of instruction in the lower standards. The general scope of the circular is to promote in the schools for older scholars the natural methods of instruction adopted in the best infants' schools, by which the children are trained to use their powers of observation and reasoning. With reference to the matters in which your Committee are more immediately concerned, it states: 'It should be borne in mind that object-lessons cannot be dispensed with if habits of observation are to be duly fostered, and they should be treated as a means for mental exercise, and not merely as opportunities for imparting miscellaneous information. Objects should always be present and in sufficient numbers, and the chief aim should be to call into activity observation and the construction of clear mental pictures, so that the intelligence of the pupils may be exercised and developed. Geography, where it is a class subject, should be treated in a similar way, and should be taught by visible illustrations and by actual modelling in sand and clay, for the production of miniature rivers, mountains, &c.'

Reference has been made in previous reports to the important work being done by the science demonstrators under the London School Board in introducing practical lessons into the schools—lessons in the course of which the children are not merely orally instructed, but are led to carry out themselves a series of simple measurements and to make experiments with the object of solving easy little problems, being thus taught both to be accurate and to be self-reliant. The vacancy in the staff caused by the appointment of Mr. Gordon, who has been so eminently successful in this work, as one of the Inspectors under the Science and Art Department has been filled by the appointment of Mr. Heller, an Associate of the City and Guilds of London Institute for the Advancement of Technical Education. He will carry on the instruction under the scheme given in the Appendix, which is no ideal scheme, but an outline of the work actually done in a considerable number of London schools during the past three years. No other School Board appears as yet to have attempted to give systematic practical instruction on such lines with the object of training children to gain their knowledge by their own efforts, thereby training them to help themselves and to think logically; but the work of the London Board has been carried on with such satisfactory results, and the method adopted is of such promise, that it is to be hoped that the example of this Board will be generally followed. The immediate difficulty that will be met with in this direction, however, arises from the lack of suitable teachers, and it cannot be too strongly urged that no time should be lost in organising classes for teachers and placing them under competent instructors. As County Councils have in some places already shown willingness to assist in this direction, it is to be hoped that progress will not be prevented by want of funds, and that School Boards and County Councils will effectively co-operate in this great work, the national importance of which must ere long be recognised.

Practical lessons similar in character to those which have been given in some of the boys' schools are about to be added to those now given in some of the girls' schools under the London Board. The results of this experiment will be awaited with the greatest interest, although there can scarcely be a doubt as to their proving to be equally satisfactory. When the character of the household work done by women is taken into account, it is obvious that training can be imparted at school in the course of such experimental lessons as are to be given to the girls which will be of direct practical value, and the most effective preparation possible for much of women's work. If girls can be taught to weigh and measure accurately, and to understand the use of a thermometer, and if they acquire but the most elementary understanding of the nature of food and of the operations incidental to cooking by actually experimenting while at school, the foundation of habits will have been laid and knowledge will have been gained which will make them far more careful, competent, skilful, and trustworthy when, later on, they become cooks or nurses or wives or mothers. It is not too much to hope that a really satisfactory method of teaching domestic economy and housewifery may ultimately be devised on the basis of experience gained in the course of lessons such as are here referred to.

Your Committee observe with satisfaction that the Royal Commission on Secondary Education comprises direct representatives of the Board School system, and some who have interested themselves much in technical instruction. In the present reorganisation of our scholarship arrangements it is to be hoped that the proper co-ordination of the studies in Natural Science will be duly cared for.

APPENDIX.

Addition to Alternative Courses in Elementary Science.

Course H.—Experimental Arithmetic, Physics, and Chemistry.

N.B.—Instruction in this subject should be experimental, the experiments being carried out by the scholars.

Standards I. and II.—Addition, subtraction, multiplication, and division of whole numbers experimentally ascertained by measurement of lines in inches and centimetres, the number of squares in a given area of squared paper ascertained by counting.

Standard III.—Decimals. Inch and centimetre rulers to be used, the inches and centimetres being divided into ten parts. Addition and subtraction, the same method to be used as in Standards I. and II. Results in each case to be recorded in columns. Multiplication and division of above by whole numbers.

Standard IV.—Metre, its subdivisions. Addition and subtraction of lengths containing them. Results to be recorded in columns, as in Standard III. The gramme and its subdivisions treated similarly. Application of above to numbers generally.

Standard V.—Measurement of length, area, volume, and weight. English and French systems, relative weights of liquids and solids. Barometer. Thermometers, graphic representation. Distillation. Filtration.

Standard VI.—Evaporation. Wet and dry bulb thermometer. Solubility. Chalk and lime, their properties. Heat and acids on chalk, limestones, &c. Chalk = lime + chalk gas. Chalk gas on lime and lime water. Chalk gas in the air. Mortar.

Standard VII.—Substances burnt in air, such as coal, sugar, &c., also metals, such as iron, copper, &c. Investigation into the increase in weight of certain metals when burnt. Rusting of iron. Candle, phosphorus, sulphur burnt in air confined over water. Active and inactive parts of air. Composition of air. Dilute acids on zinc and iron. Inflammable air and the formation of water therefrom. Inflammable air over heated red lead. Composition of water. Steam over heated iron filings. Hard and soft water.

Methods of Economic Training in this and other Countries. Report of the Committee, consisting of Professor W. CUNNINGHAM (*Chairman*), Professor E. C. K. GONNER (*Secretary*), Professor F. Y. EDGEWORTH, Professor H. S. FOXWELL, Mr. H. HIGGS, Mr. L. L. PRICE, *and* Professor J. SHIELD NICHOLSON.

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IN furtherance of the above purpose three reports have been drawn up after due inquiry and laid before your Committee.

These reports, which are appended, bring out very clearly some features of difference between the position of such studies in this and in foreign countries, and, with other information before your Committee, seem to them to call for the following observations. Before proceeding to the consideration of certain particular points they would remark that the growth of economic studies, and in particular the development among them of the scientific study of the actual phenomena of life (both in the past and in the present), have important effects, so far as the organisation of the study and its suitability for professional curricula are concerned. It may be hoped, indeed, that when the empirical side is more adequately represented, the importance of the careful study of Economics as a preparation for administrative life will be more fully recognised both by Government and the public.

(a) *The Organisation of the Study of Economics.*—While fully recognising the great energy with which individual teachers in this country have sought to develop the study of this subject, your Committee cannot but regard the condition of economic studies at the universities and colleges as unsatisfactory. As contrasted with Continental countries and also with the United States, the United Kingdom possesses no regular system. In one place Economics is taught in one way, and in connection with some one subject, not infrequently by the teacher of that subject; in another place in another way, and with another subject. Very often it is taught, or at any rate learnt, as little as possible. In most places this lack of organisation is due to the weariness of introducing elaborate schemes for the benefit of problematic students. At Cambridge the pass examination which has recently been devised only attracts a few. With regard to the higher study of Economics, Professor Marshall, among others, has written strongly of the comparatively small inducements offered by Economics as compared with other subjects. He adds: 'Those who do study it have generally a strong interest in it; from a pecuniary point of view they would generally find a better account in the study of something else.' Some considerations bearing on this point are offered below, but here it may be observed that the attempts to introduce more system into the teaching of Economics, and to secure for it as a subject of study fuller public recognition, should, so far as possible, be made together.

In the opinion of your Committee Economics should be introduced into the honour courses and examinations of the universities in such a manner as to allow students to engage in its *thorough and systematic* study without necessarily going outside the range of degree subjects.

(b) *The Position of Economics with regard to Professional and other Curricula.*—In most Continental countries Economics occupies a place more or less prominent in the courses of training and in the examinations through which candidates for the legal profession or the civil service have to pass. In Austria, Hungary, and the three southern states of Germany this connection is very real, and the nature of the study involved very thorough. The same cannot be said with regard to the Northern States of the latter empire, where the importance attached to this subject is so slight as to make its inclusion almost nominal. To some extent or in some form it is regarded as a subject obligatory on those preparing for those callings, or, to speak more accurately, for the legal calling and for certain branches of the civil service in Italy, Spain, Sweden, Norway, Denmark, and Switzerland. In Holland and Belgium, while a certain general knowledge only is required for a few posts or branches of the civil service, a very thorough study is incumbent on those qualifying for the higher branch of the legal profession. In both France and Russia it is an integral and necessary portion of the legal curriculum.

The two studies are cognate, and according to the view of your Committee not only would the institution of an examination in Economics at some stage of legal degrees and qualifications be advantageous professionally, but the work of those who had enjoyed a legal training would react favourably on the advance of the science. In addition, Economics should receive a much more important place in the Civil Service Examinations, and should, if possible, be made compulsory on those entering the higher branches.

APPENDIX I.

On the Methods of Economic Training adopted in Foreign Countries.

By E. C. K. Gonner.

The comparative study of the Continental and other foreign systems of Economic Education brings out in clear relief certain features of either difference or coincidence which relate respectively to the impulses or circumstances giving this particular study its importance, to the method of study, and, lastly, to its organisation and the degree of success attained in the various countries.

(1) Putting on one side the purely scientific impulse to learn for learning's sake, which can, after all, affect comparatively few, the inducement to a large or considerable number of students to interest themselves in any particular study must consist in its recognition, either positive or tacit, as a necessary preliminary to some professions or to certain positions. This may, as has been suggested, be either direct and positive, or indirect and tacit; direct and positive, that is, in the case of Economics when in either one or more branches they are made part of the examinations admitting to the legal profession and the higher civil service; indirect and tacit when public opinion demands economic knowledge as necessary in those holding prominent positions as citizens or anxious to direct and control their fellows, either by the pen as journalists, or by act or word as statesmen or politicians. The importance of both these motives is, of course, largely increased when they exist in close connection with the purely scientific impulse. By itself this is not sufficient. The exclusion of one study, as Economics, from professional or technical curri-

cula, unless counteracted by the existence of a very powerful popular sentiment in its favour, practically removes it from the reach of students who have to make themselves ready to earn their living. Of the two influences, described above, the former, or the actual and positive recognition, is given, in some shape or other, in Austria and Hungary, the southern states of the German Empire, France, Belgium, Italy, Spain, Switzerland, Sweden, Norway, Denmark, Russia, and Holland. In America, and to some extent in Canada, popular sentiment and interest supply the needful impetus by making Economics a tacit requisite for those exercising particular callings. In both Germany and Austria there are signs of the growth of Economics in popular appreciation. In Austria, indeed, the circumstances are peculiarly fortunate. Economic instruction is recognised as a matter of serious importance, while, on the other hand, economic knowledge is one of the subjects of the State examinations for the legal and administrative service. In addition, its careful and scientific study is pursued by a fair number of advanced students. In this way Austria occupies a central position among the various nations which range themselves with America at one extreme, where there is no positive or direct obligation in favour of economic study, and at the other extreme, the Scandinavian and lesser Latin countries, where all recognition that exists is positive, but where this positive recognition is largely nominal.

It has been urged that the ill-success of economic studies in these latter countries is largely an argument against their inclusion in obligatory curricula—a proposition which probably those who make it would hardly apply to the cases of other subjects. But from the evidence furnished by the countries before us this ill-success can be traced to other causes. It is due, firstly, to differences in the methods of study, and, secondly, to the differences in the thing made obligatory. In South Germany, Austria, and Hungary, Economics is obligatory on certain classes of students, and the study of Economics is making rapid and satisfactory progress; but then in South Germany, Austria, and Hungary, the method of study is one which commends itself to advanced students and educational critics, and the knowledge required in the examinations is thorough. In the lesser Latin countries, as Spain and Italy, the knowledge which the candidate is expected to show is elementary in itself, largely confined to elementary theory, and a marked unreality is imparted to the whole study, an unreality recognised alike by examiners, teachers, and students. On the other hand, the advantages which Economics may receive from its public and positive recognition are borne witness to by those best acquainted with the condition of the study in Germany, where the usages of the north and south differ. Broadly speaking, they consist in the removal of Economics from the category of unnecessary to the category of necessary acquirements. Many of those who begin the study from compulsion continue it from choice. In America, indeed, the strength of popular sentiment and the ever-present interest of politics together with the action of the universities, where nearly all studies, and not Economics alone, are put on a voluntary footing, give it an adequate position; but failing the combination of conditions such as these, its absence, both from all professional curricula and from the earlier stages of education, cannot but be regarded as disastrous and unjust.

(2) The method of economic studies is of a certain importance with regard to the subject last discussed. Though it would be unfair to estimate the work, or to judge of the scope of schools of economic teaching

from their extreme tendencies, these afford not unsatisfactory means of distinction. Speaking broadly, they may be placed in two groups—those in which the dominant influence is realistic or empirical; those in which it is theoretical or abstract. Very few economists, whether teachers or writers, are wholly realistic or wholly theoretical. Some bias, however, they nearly all have, and it is by that they may be ranked for the present purpose. Nor must it be supposed that the distinctions drawn in one country, with regard to these opposing lines of study, at all correspond with those existing in another. In Germany, for instance, the attitude of Professor Wagner is attacked by the members of the historical school—one branch of the empirical—but judged by the standards of France and England he would rank in the main as an empiricist. The theorists of Germany and Austria do little more than assert that theoretical study has its due place and is a necessary part of the equipment of an economist.

When discussing the assertion that compulsory Economics, however enforced, tended to issue in perfunctory attendances and poor results so far as interest was concerned, it was urged that these consequences depended largely on the method and nature of study. This is remarkably illustrated by the fact that the countries where such evils are regretted or anticipated are those where the study of Economics is mainly theoretic, or where Economics is distinctly and openly subordinated to other subjects. Lessons of this latter kind are never thrown away upon students. But with regard to the former, it is not from the southern states of the German Empire, or from Austria, that we hear these complaints. There economic study is obligatory, and the economic study involved is two-thirds of it empirical in character. In the Latin countries the state of things is very different. The basis of study is, if I may say so, text-book theory, and the position of Economics, so far as progress is concerned, is unsatisfactory in the extreme. This has been particularly dealt with in the paragraphs relating to Italy.

In two of the great nations the mode of study practised is largely empirical. In Germany, despite the contrast between different leaders of thought, the importance of this method is well illustrated by the position which the study of Practical or Applied Economics invariably occupies. In America, the study of economic history and of modern economic fact grows into greater prominence year by year.

(3) Turning to the question of success, the question arises at once as to the tests whereby such may be measured. Of these, many, varying from popularity to eclecticism, have been suggested, but possibly the one most suitable is the ability of a system to produce a high general level amongst a good number of students. Something more is required of a system than that it should bring together large audiences for elementary courses; while, as for the production of a few very good students, a few will always press to the front through all difficulties, despite systems good or bad, or in the absence of any system at all. But a system that is to be deemed good must place within the reach of all industrious and apt students the means of a good general economic training, while stimulating him to prosecute original and independent work. Further, it should provide these advantages regularly and not intermittently. The way in which these two needs are met in practice can be stated briefly. General training is provided by a systematic series of courses which should include at least Theory of Economics, Applied Economics, and Finance. The

seminar, or classes organised like the seminar, offer opportunities for guiding a student into the ways of original work.

Seminar instruction is given regularly in Germany, Austria, Hungary, in the better equipped universities of America, Switzerland, and to some extent in both Sweden and Holland. In Russia the professors may and *sometimes* do organise seminars or discussion classes. In Belgium, classes are held in connection with some of the courses.

With regard to the systems of providing for a good ground knowledge of the leading branches of Economics, classification is rendered difficult by the different methods adopted in the various countries. Some are more, some less thorough. Among the former we may put without hesitation the countries already singled out for notice—Germany, America, Austria, and Hungary.

From the accounts given in detail below it is clear that in these countries the study of Economics is advancing. The training is systematic. A fair proportion of students pass from the more general into the more special or advanced courses. The production of work, not necessarily of the first order, for with that we are not dealing, but of the second, or third, or fourth order, is great and still increases.

AUSTRIA.

The position of Economics in Austria is largely determined by its relation to legal studies—by the place, that is, which its various branches hold in the examinations qualifying for the legal profession and for the juridical and higher administrative services. According to the system till recently in force, but now somewhat modified, candidates intending to enter these had to attend certain courses at the universities, and to pass certain examinations varying according to the positions sought. Those entering the legal profession had to pass the first State examination in addition to the three *political rigorosa* of the university, success in which latter conferred the degree of Doctor. Other candidates only needed to pass the three State examinations. These latter were as follows:—The first (Rechtshistorische Staatsprüfung) was held at the end of the second year of study, and comprised the following subjects: Roman Law, Canon Law, and German Law in its historical aspect. The second (Judizielle Staatsprüfung) was held towards the end of the eighth semester, in the following subjects: Austrian Law, civil, commercial, and penal; Austrian Civil and Criminal Procedure. At the end of the four years came the third and final examination (Staatswissenschaftliche Staatsprüfung), which alone is of importance so far as the legal recognition of Economics is concerned. The subjects examined in were Austrian Public Law, International Law, Economics (including Economics, the Science of Administration, Finance, and Statistics). The political rigorosa, while they correspond in outline to the State examinations, have some few points of difference both with regard to method and subjects. They, too, are three in number, and may be described as the Austrian rigorosum, corresponding to the second State examination, the Romanist, corresponding to the first State, and the Staatswissenschaftliche, which closely resembles the third State examination, though not including Statistics or Administration. There is no regulation as to the order in which they are to be passed, but that indicated above is fairly customary. Their greater severity may be judged from both the additional length of preparation prescribed and the manner in which they are conducted. The earliest date at which a candidate may pass his first rigorosum is at the end of the fourth in place of the second year. The second and third may follow at respective intervals of two months. The Staatsprüfung is an examination taken by groups of four students, each group being under examination for two hours; but in the rigorosa each candidate is under examination for two hours, spending half an hour with each examiner. Both State and university examinations are oral, and the latter are said to impose a severe strain on both examiner and candidate. In the latter the examiners are the university professors, while in the State examinations these are variously composed of professors, functionaries of the State, and barristers of good standing.

By the Law of April 28, 1893, which came into effect in October, the system sketched above underwent certain alterations. A complete separation will be effected between the university examinations or rigorosa and those qualifying for the legal profession and State services, the former no longer serving as a possible substitute for the second and third of the latter. In addition, some slight change has been introduced into the curriculum and examinations imposed upon students designing to enter these. They will have to attend courses and to be examined in—(*a*) The Science of Administration (Verwaltungslehre), and with special reference to Austrian Law; (*b*) Economics, theoretical and practical; (*c*) Public Finance, and especially Austrian Finance. In addition they must attend lectures (without subsequent examination) on Comparative and Austrian Statistics. These alterations will leave the number of students in the more elementary subjects unaffected, and, so far from operating in discouragement of economic and political studies, will, it is hoped, lead to their more thorough prosecution, by raising the degree to a more scholarly position.

The marked recognition of Economics by the State, and the large number of students whose prospects are involved in its successful study, naturally affect the teaching organisation provided by the universities and other bodies.

This is fairly uniform throughout Austria, as apart from Hungary, though the extent to which the subject is pursued, and the variety of its forms, depend mainly on the enthusiasm of particular teachers and the greater opportunities offered by particular universities or other institutions. At the universities[1] the ground plan of work may be described as identical, Economics being taught in the faculty of law. There are certain courses which must be delivered, and at which attendance is obligatory for certain classes of students. These are on *National Economy, Finance, Statistics*, and the *Science of Administration* (Verwaltungslehre), which includes instruction in practical economics, public health, army, matters of policy, justice, &c. But in addition to these the teachers, whether professors or privat-docents, may, and often do, deliver special courses dealing with more particular subjects. These are not necessarily or usually the same from year to year; and may be described as instruction of an unusually high order, inasmuch as each teacher is accustomed to select for treatment such branch of science in which his own activities and studies lie. The large[2] voluntary attendance at such lectures is a testimony to the regard in which economic studies are held among a large body of students.

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[1] Vienna—Prag (German), Prag (Bohemian), Graz, Innsbruck, Krakau (Polish), Lemberg (Polish), Czernovitz.

[2] At Vienna the attendance at special courses varies from 50 to 100.

Seminar instruction is customary, as in Germany. At Vienna there are two seminars, one for Economics (Staatswissenschaftliche), one for Statistics, while in addition there is an Institute of Political Science, attached to all of which are libraries and places for the members to carry on their work in close contact with their professor or his deputy. The members consist in part of young doctors of the university who have recently graduated, in part of those preparing for the examinations of the university, and include, as a rule, several foreigners who have come to Vienna to pursue their studies. The arrangements at the other universities are similar, though in some they lack the completeness displayed at Vienna.

Students who, having passed their examinations with credit, or other wise performed their work to the satisfaction of their teachers, wish to carry on their studies in other countries are eligible for Reisestipendia (travelling scholarships). These are rewarded to encourage study in foreign universities, or to enable their holders to carry out investigations which necessitate a journey. Unfortunately they are but few in number, and as they are open to students of all faculties, few economists can hope to obtain them. Among the more recent holders in Vienna are Professors Böhm-Bawerk, Robert Meyer, Von Phillipovich, and Dr. Stephen Bauer, the two latter of whom published reports on matters studied abroad.

In this way a method of economic instruction has been developed in the Austrian universities which not only provides a large number with a carefully systematised series of courses, but offers to those disposed to more thorough or more special study ample opportunity. The more eager and energetic pass through the courses compulsory for the law degree, in themselves a fitting preliminary to more detailed work, to attendance at the special courses and membership of the seminar; from these they may, if fortunate, advance into the position of travelling or research scholars of their university. Though most of the students at the economic lectures are jurists, the attendance frequently includes members qualifying in other faculties, or even more general 'hearers.' At Krakau, students of the philosophical faculty form some 20 to 25 per cent. of the total. All these students are entirely free so far as their choice of economic courses is concerned. It is not possible to give the exact numbers of the students to be described respectively as elementary and advanced. The particulars, however, furnished by the various universities permit a rough general estimate. Not fewer than one thousand students undergo the more general courses, thus attaining to a fair systematic acquaintance with the main branches of economic study, while out of that number more than two hundred take special courses and enter the various seminars. This account rather under than over estimates the extent to which economic studies extend. As to the character of the advanced work there is no doubt. As has been pointed out, it is of a high order. But some question has been raised as to the value of the knowledge likely to be attained by the more general student. The variety of subjects required in the examinations either of the university (political rigorosa) or of the State, and the number of courses obligatory on the students, do not allow of an early specialisation.[1] But a glance at the nature of the examination, and at the syllabus of the various courses, forbids the inference that the instruction given is of a purely rudimentary nature.

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[1] This, as Professor von Milewski contends, interferes with the scientific character

Much, it is true, depends upon the personal enthusiasm and force of the teacher, for, despite the obligation of attendance, a dull and uninteresting lecture will rarely obtain the audiences registered to him, many students preferring to buy copies of the course hectographed from the notes of their predecessors in the lecture room, and only troubling themselves to appear at the beginning and end of the semester.

In the University of Krakau, Economics is obligatory, both in study and examination, for the students of agriculture who attend special lectures, apart, that is, from the law students. Instruction in Economics (Political Economy, Finance, and Statistics) is given also at all the Technical High Schools (Technische Hochschulen) in Austria,[1] while attendance at the courses (though without examination) is obligatory at the schools of agriculture, where similar conditions prevail. At the Commercial Academies (Handelsakademien) of Vienna and Prague a course of lectures is given with particular reference to the economic branches which throw most light on commercial facts and features, and on the relations existing between the various classes engaged in industry and trade. To obtain the diploma of these institutions the lectures are followed by an examination. Courses are provided for the consular service at the Oriental Akademie in Vienna, and for the service of the administration of the army.[2] There is also a Fortbildungschule for officials of the railway, where political economy is taught and examined in. Members of these courses are considered specially fitted for the attainment of the higher posts in their service.

A knowledge of Economics, duly and doubly certified by registered lecture courses and by examination, is a necessary preliminary to certain careers. Attendance at the university lectures and the attainment of the juridical degree are the qualification for the higher branches of the legal profession (advocate, &c.), and like attendance and degree, or, in the place of the latter, the diploma of public service, are required for all branches of the legal profession and for the whole civil service. Entrance into the consular and diplomatic services may also be obtained through the courses of the Oriental Academy. Further, as has been pointed out above, a certain acquaintance, or supposed acquaintance, with economic studies is considered necessary in some other vocations.

At the present time very considerable importance is attached to economic studies in Austria. Their scientific character is a general matter of care, and an extension of the sphere in which they are obligatory, or at least advisable on the part of those who seek success in their particular calling or profession, is earnestly advocated by some. In the first direction the reforms in the juridical studies at the universities will operate. As Dr. Mataja writes :—'Economics will have greater and not

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of the various studies required for the degree. As each has to take up several subjects, and to pass examinations in these, he cannot give very special attention to Economics or any other branch of social science in which he may happen to be interested.

[1] Of these there are six :—Vienna, Brünn, Graz, Prag (German), Prag (Bohemian), Lemberg (Polish). After examination diplomas are granted, which are necessary for those becoming teachers in agricultural schools, and are, it is said, a strong recommendation in the eyes of landlords when engaging their officials, agents, &c.

[2] An Intendanz-Class for officers willing to serve as Intendanten for the provision of the army.

less weight.' On the other hand, and in the other direction, different suggestions have been made. Some advocate the extension of compulsory study to engineers who will become officials and directors in factories, to the *employés* of the fiscal service, to those attending the more elementary technical schools. Others would like to see schools of political and social science (including Economics) founded in the great industrial centres. Whether these suggestions be carried out or not, they serve to illustrate the feeling which exists, at least on the part of some, with regard to the value of Economics both as a special and as a branch of general study.

HUNGARY.

Economics holds a position somewhat similar to that in Austria. It is obligatory on all students in the faculty of law and political science at the two universities,[1] and in the Rechtsakademien (legal faculties, as at Kassa), who must take courses in Economics and Finance before the end of their second year, when they have to pass an examination, among the subjects of which these are included. After the second year their studies bifurcate, according to the degree which they seek (Dr. Juris, or Dr. Politics). In order to obtain the former, they must also pass an examination in financial law. But if they wish to take the latter degree (Dr. Politics), they must pass two rigorosa, among the subjects of which are Economics (theoretical and practical), Finance, Finance Law, and Statistics. The knowledge required in this case is exceedingly thorough, and the degree is of high value in the public service. There are also State examinations which serve as qualifications, though to a lesser extent, for the legal and administrative services. Though easier, they correspond closely with the above. In the universities the system of economic study in its general features resembles that in vogue in Austria, the chief courses being those on Economics and Finance ; but both at Budapest and Klausenburg (Kalozsvar), as, for instance, at Strassburg to take a parallel, these studies belong not to a sole legal faculty, but to a legal and political faculty (Rechts- und Staatswissenschaftliche Fakultät). In addition to successful examinations the candidates have to present a thesis. The possession of the degree of Dr. Cameralium implies a very sound economic training, and it was till lately the chief means of entering the higher civil service both of the kingdom and of the States. Considerable attention is paid to Economics, the seminars being well frequented, and the interest and activity of students great. This is particularly true of Budapest, where the lectures are varied and delivered by a numerous and able staff.

GERMANY.

The differences in the history and regulations of the various States composing the German Empire have led, not unnaturally, to considerable differences in the positions which economic studies occupy. On the one hand, they are affected by the diversity of usage existing as to their connection with the course of study required for the legal profession and the civil service. On the other hand, the particular faculty in which they are included has been determined by reasons possessing little but historical validity.

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[1] Budapest, Klausenburg (Kalozsvar).

1. *Prussia.*—At the Prussian universities Economics belongs to the faculty of philosophy, and, speaking generally, to that section of this faculty known as the Sciences of the State. A student takes his degree in Economics entirely apart from law, the position of which as a separate faculty unfortunately precludes a student who presents a thesis in one of these two subjects from selecting the other as one of the two collateral subjects which he is bound by regulation to offer himself for examination in. Further, it must be noticed that the degree of doctor in this country, and, indeed, in Germany generally, is not a *qualification*, as was till recently the case in Austria and still is in certain of the Latin countries. Some assistance it may be in a judicial career, but even then the degree of Doctor Juris has naturally much more value than that of Doctor of Philosophy in the State Sciences.

Nor does Economics occupy an important place in the State examinations which qualify for the legal and administrative services. To enter these a candidate must pass examinations, the first of which is common to both services (*referendar Examen*). This consists of two parts, the first written and dealing with law, the second oral, which includes, among other matters, the elements of Economics. So subordinate is this subject that, in the opinion of many critics, it hardly counts in the decision as to the eligibility of candidates. The course of examination then bifurcates, some taking that for Justiz-Assessor, others for that of Regierungs Assessor, for neither of which is Economics required. At the latter of these (Reg. Assessor) some knowledge of Economics in its applied branches is said to be highly desirable; but inasmuch as the examination takes place some five years after the conclusion of the university course, the demands it makes are chiefly met by knowledge supplied from books. With regard to the constitution of the examining boards, it should be noticed that, even at the *referendar Examen*, it is not in accordance with common practice to include professors of Economics.

2. *Saxony.*—The system recently adopted in Saxony is, in so far as the subordination of Economics is concerned, nearly identical with that of Prussia. In one point it is more favourable to the interests of this subject, the professoriate being invariably represented on the board of examiners.

3. *Reichsland.*—In the Reichsland Economics is of no more importance than it is in Prussia.

4. *Saxe-Weimar.*—In Saxe-Weimar, too, it is of but nominal importance in the juridical examinations. There, too, the board of examiners is constituted irrespective of economic requirements, and, as has been caustically said, it is rare to find the examiners academically qualified in the subjects in which they are supposed to examine. The position, in the main, is very similar to that prevailing in Prussia.

5. *Bavaria.*—In the chief southern and south-western states Economics holds a more important position in the legal and civil service curricula. Thus, in Bavaria, all students of law, administration, and forest (Landwirth) have to pass an examination in which it forms one of the subjects. The time of the examination is at the conclusion of the four years devoted to legal or other studies respectively, and the presence of the Professor of National Economy among the professorial examiners necessitates due attendance at lectures and thorough study. The second examination for the civil service is technical in character, and only

requires economic knowledge in its connection with practical developments and issues.

6. *Würtemburg.*—In Würtemburg, though Economics forms no part of the strictly legal examinations, in the other State examinations for administrative students it is of very great importance. For these there are two examinations, the first of which, more general in character than the other, takes place at Tübingen, and involves a very considerable acquaintance with Economics.

7. *Baden.*—Every legal student, as well as every candidate seeking entrance into the higher employments in the State departments of revenue and administration, must, in his time, attend lectures on, and pass examinations in, the economic and financial sciences.

The varying positions which Economics holds in the examinations qualifying for State and legal employment in the different German States affect a large number of university students who have to pass these examinations but do not of necessity take a degree. To them the connection of Economics with one faculty or the other in the university cannot be a matter of much importance, but with others the case is different. Students reading for the degree are, as has been already said, restricted now on one side, now on another, as to their choice of collateral subjects for examination. Sometimes they can offer Economics in connection with law, sometimes they cannot. In addition, the influence which kindred studies taught in one faculty may bring to bear on the methods of instruction may, in some instances, prove of not inconsiderable importance even in the case of the students studying for the doctorate. Professor Brentano, however, whose personal experience extends from Leipzig to Strassburg, from Vienna to Breslau and Munich, contends that the varieties of combination matter less than might seem probable. The facultative position of Economics varies considerably. In Prussia and Saxony they find place among the many heterogeneous subjects grouped together in the faculty of philosophy, though in certain places, as at Berlin, they fall into a distinct subdivision. At Berlin they belong to the *Staats- Cameral- und Gewerbewissenschaften.* At Strassburg (Reichsland) they combine with law to form a *Rechts- und Staatswissenschaftliche Facultät.* At Tübingen (Würtemberg) a *Staatswissenschaftliche Facultät* exists independent of the law, a practice identical with that current at Munich (Bavaria). At some universities, as for instance at Jena, economic lectures are largely attended by the students of *Landwirthschaft.*

A comparison of the studies preliminary to the doctorate in Germany with those in Austria reveals two chief points of difference. At German universities there is little prescription of the course of study, or, indeed, of the methods to be adopted by the student, who within certain wide limits has a perfectly free choice of subjects. But this comparative freedom from restraint is closely connected with the great importance attached to the thesis, a custom which, its critics urge, leads to premature specialisation. In both countries candidates for the civil and legal services are much more closely restricted to definite courses.

In their practical working the systems of the different universities bear a close resemblance, at any rate in their earlier stages. There are three main courses, delivered annually, on pure Economics, Applied Economics, and Finance, all of which, even the first, involve a careful study of economic fact as distinct from hypothesised theory. The extent to which the method adopted in the first course is empirical depends, of course, on the position of the teacher as an adherent of one or other of the opposing schools of economic thought; but, speaking generally, even the least empirical among them would be deemed empirical by those accustomed to English methods. But, in addition to these three annual courses, lectures are delivered on special subjects. At Freiburg (in Baden), in the summer semester of 1891, these were:—

History of National Economy and Socialism.
Agrarian and Industrial Policy, including the Labour Question.
History of Statistics.

The list of special lectures at Berlin, to take the most completely equipped of the universities, shows more clearly the wide range of subjects dealt with under the term Economics. In the summer term, 1892, besides the ordinary annual courses, there were courses of lectures on the following subjects:—

Theory of Statistics.
History of Statistics.
Statistics of the German Empire.
The Economic and Social History of Germany from the end of the Middle Ages to the Peace of Westphalia.
History and Modes of Industrial Undertakings.
Money and Banking.
Early Commercial and Colonial Policy (till 1800).
Industrial and Commercial Policy.
The Social Question.
Forms of Public Credit.

In addition to lectures, necessarily more or less formal, opportunities are afforded for systematic instruction in classes and in the seminar. The latter institution varies considerably, according to the character of the students frequenting particular universities, for its efficiency, and according to the position of the professor undertaking it, for the direction of its studies. Each teacher collects around himself a group of students who follow his method, adopt his attitude, and frequently devote themselves to those branches of economic research which have occupied his attention. Thus, at Strassburg, Professor Knapp's seminar deals chiefly with agrarian questions; at Berlin, Professor Wagner's influence is seen in the predominance of finance and financial topics among the subjects discussed. At Munich, to pass to the question of organisation and method, the two professors join in holding a seminar in which 'there are about twenty-four young men taking part. Each of them has to undertake some work: the younger ones get a book to read, and have to report on it; the more advanced have to treat a subject after reading several books on the subject; the most advanced have to make a work themselves, the professors aiding them in furnishing material and giving assistance.' At some universities there are two seminars, at others one. It is a matter for regret that, with all these opportunities, a comparatively small number of students are ranked as advanced. The explanations offered are many, but probably a very adverse effect on the study is produced by the paucity of the positions to which a thorough economic study can serve as an introduction. Teaching posts are few, and the requirements in the State examinations for the legal and administrative services are, if not as in many cases nominal, strictly limited to an elementary knowledge.

In some of the technical schools, and in all the schools of commerce, instruction in some branch of Economics forms part of the regular course, and, in these latter, an examination is held. In the former, however, the subjects thus taught are distinctly subordinated to the technical sciences, which occupy the chief attention of the students, while in the schools of commerce only those branches receive adequate treatment which bear or appear likely to bear upon commerce in its practical aspects.

HOLLAND.

The connection between the universities and the legal profession is close in Holland, none but doctors of jurisprudence being qualified to practise as advocates. This is a circumstance which has a material effect upon the study of Economics, inasmuch as this, in its more elementary branches, forms one of the obligatory subjects of the first examination for the degree. Thus, so far as this one profession is concerned, a certain knowledge of Economics is necessitated.

In the higher administrative service no such knowledge is obligatory, but it is considered that officials who possess the degree of Doctor of Political Science have better chances of promotion. For this degree a thorough study of Economics is required. In certain other Government services demand is made for acquaintance with certain branches of the subject. In the examinations for the consular service the 'General Principles of Economics' and the 'Elements of Statistics,' chiefly with regard to trade and shipping, form subjects of examination. A similar knowledge is required for the diplomatic service. In none of these cases, it should be noted, is attendance at specified courses compulsory. The subject forms part of the examination.

The requirements indicated above explain to some extent the position which Economics occupies in the four Dutch universities. It is a necessary subject for two degrees—the doctorate in laws and the doctorate in political science. But the nature of the knowledge required differs greatly. In the former it is elementary, not going beyond the first principles of the theory, while in the latter case the examination necessitates a really careful and detailed study. In addition to the general course of lectures taken by all, candidates for this latter distinction usually attend two other courses, one in *capita selecta* (taxation, finance, socialism, &c.), and another in statistics. These courses, unlike those at German universities, extend throughout the academic year—i.e. from September to July. For advanced students discussion classes are held, where the students, after a previous study of a chosen subject, meet to discuss it among themselves and with the professor. Before proceeding to the degree of Doctor a candidate has to write, and afterwards to defend, a dissertation on some branch of the general science which he has taken up. Thus, in the case of political science, the thesis may be on some economic question. Outside the universities the chief study of Economics takes place in the intermediate schools, where, during the fourth and fifth years of the five years' curriculum, it is taught for two hours weekly by a Doctor of Political Science, or by another teacher duly qualified by a special examination. At the Polytechnic at Delft there is a chair of Economics, but neither is attendance at the course obligatory, nor does it form one of the subjects of examination.

BELGIUM.

By the Law of 1890, which provides the regulation for higher instruction, political economy is made obligatory for the attainment of the degree of Doctor of Laws, a distinction proving a professional qualification, and for the grade of engineer, the course for the former involving some forty-five lectures, that for the latter some fifteen. In both cases the subject is taken in the earlier years of study. Students training for these professions would appear to form the great bulk of those attending economic lectures at the universities. In neither case can the course be said to furnish more than elementary instruction.

The universities have made provision outside these State requirements for more advanced students. The candidates for the degree of Doctor of Political Science have to show a more thorough acquaintance with economic subjects. At the University of Ghent the course which is provided for them is considerably longer; still more stringent regulations prevail at the University of Louvain for the degree of 'docteur en sciences politiques et sociales.' The important regulations are as follows:—

ART. 5.

Pour être admis à l'épreuve du doctorat il faut:

(*a*) Avoir acquis depuis une année au moins le grade de docteur en droit.

(*b*) Avoir pris une inscription générale aux cours du doctorat en sciences politiques et sociales et avoir suivi les cours sur lesquels porte l'épreuve.

(*c*) Présenter, sous l'approbation du président de l'École, un travail imprimé sur un sujet rentrant dans le cadre du doctorat.

ART. 7.

L'épreuve comprend un examen oral d'une heure et demie. Cet examen porte:—

(*a*) Sur six branches portées comme principales au programme de l'École.

(*b*) Sur deux branches au moins choisies parmi celles qui sont portées comme branches libres au programme de l'École ou—avec l'autorisation du président de l'École—parmi celles qui sont portées au programme de l'université.

(*c*) Sur le travail présenté par le récipiendaire.

The list of lectures for the two years' curriculum, 1892–3, 1893–4, is as follows:—

For the first year—Histoire parlementaire de la Belgique depuis 1830, la législation ouvrière comparée; le droit public comparé; de la neutralité de la Belgique et de la Suisse; du régime légal des sociétés commerciales en droit comparé.

For the second year—Histoire diplomatique de l'Europe depuis le Congrès de Vienne; l'évolution économique au XIX^e siècle; les institutions de la France et de l'Allemagne; le régime colonial et la législation du Congo; les associations en droit comparé.

Seminar or class instruction is given at the universities, though the particular form it takes varies with the other organisation provided, and the character of the students. At the University of Ghent a class supplementary to the lectures is formed, where discussion takes place; at Louvain Professor Brants directs a 'cours pratique,'[1] the members of which (some dozen in number) write treatises, discuss economic movements, and make excursions to centres presenting features of economic interest.

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[1] Conférence d'Économie Sociale. Rapport sur ses travaux, 1891–92. Louvain.

ITALY.

Outside the universities there are in Italy but few institutions which give much instruction in Economics. Though courses are delivered at the superior schools of commerce, as, for instance, at Genoa, Venice, and Bari, and the Polytechnic School of Milan, which compare in their nature with those existing at similar places in Austria and Germany, the main aim of such schools, and the limited extent to which they are frequented, prevent them from obtaining any control over the development of economic teaching in the country. It is, then, to the universities that we must look for information as to the methods chiefly employed. At them Economics is studied as a subsidiary subject to law, being taken by students in their second year. There are three courses at which attendance, or, to speak more accurately, inscription is obligatory on legal students. In the case of the three obligatory courses the attendance is fairly regular, owing, it is said, to the combined effect of the latitude allowed in the teaching of the subject and the position of the professor as examiner. Without passing the economic examinations students cannot attain to legal degrees. The courses are those in Economic Theory and Administration, Finance, and Statistics. According to the condition of the university these are taught by the same or different teachers, in most cases by the professors who are appointed and paid by the State. In addition to these courses others are given at the option of the teachers, either professors or docents. The attendance at these is not good, though in many cases a large number of students enter themselves as a mark of courtesy towards the lecturer. It costs them nothing, as they pay a compound fee, and it benefits him considerably if a docent, as he receives from the State a payment proportionate to the number of students registered for his courses. In addition to the examination, a candidate for the legal degrees presents a thesis which may, and not infrequently does, deal with some economic subject.[1] The study of Economics is, moreover, obligatory on students seeking the higher official careers. Many complaints are made as to the position occupied by economic studies in Italy. Their connection with law creates no doubt a certain and a large audience in the lecture room; but, as one Italian professor points out, students do not remain there long enough to acquire anything like a sufficient knowledge of the subject. They come from the schools wholly unprepared, and they leave the university without having undergone a training thorough enough to counterbalance the loose economic notions gathered from their more diligent study of the newspapers. The study of economic facts does not seem to have had sufficient place in the universities of Italy. Attempts are now being made to remedy this defect by the formation of discussion societies among the students of Economics, and the encouragement of research into statistical and similar questions.

At the minor technical schools lectures are delivered on Elementary Economics, Finance, and Statistics.

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[1] Professor Tullio Martello calculates that at the University of Bologna some 15 per cent. of those graduating in Law present a thesis dealing with Economics.

RUSSIA.

The conditions under which Economics is taught in Russia bear a superficial resemblance to those prevalent in the Latin countries, where it is annexed to the study of law, and pursued very much as a subject of secondary importance. Here, too, it forms part of the regular training through which a jurist must pass in his four years' curriculum. There are three economic courses which he must attend, and in the subject-matter of which he must display sufficient knowledge in the May State examinations. These are on Economic Theory, Statistics, &c., and Finance. In addition to formal lectures, the professors in charge of the subject may, and sometimes do, organise classes, discussion societies, or seminars, though attendance at these is not obligatory.

The provision for further and more detailed study is considerable. A student who has finished his law studies with a diploma of the first degree can remain in the university, if he wishes, for more special research in one or other subject (Roman Law, Political Economy, Private Law, Financial Law, &c.), under the supervision of the special professor or professors. Such a student is examined, and, if successful, obtains the title of Magistrandus of the subject in question. Then he must present a dissertation and defend it, after which he obtains the degree of Magister. After a second dissertation and disputation he attains the higher degree of Doctor of his special subject.

UNITED STATES OF AMERICA.

The conditions under which the study of Economics is carried on in the United States of America are widely different from those which prevail in the countries of Continental Europe. On the one hand, there is no inducement held out to students by its inclusion among the subjects of State or professional examinations. On the other, there is evidence in the importance which such subjects have assumed at the universities and colleges of a strong public sentiment in favour of their careful study far exceeding that in existence either in these countries or in the United Kingdom. In one respect the regulations of the colleges have had an important effect, independent of the action which they have taken in respect of the strong public demand. Owing to the freedom of the students in most of these institutions from prescribed and compulsory courses of study in most stages of their career, Economics has escaped being relegated, as, for instance, in England, to the position of a subject outside the usual curriculum, and optional only in some one or, perhaps, two stages. Where such prescription does exist it is not deemed a subject necessarily unfit to form part of a compulsory general course. Its inclusion, to some extent, would probably be demanded by the strong public opinion which has grown up during the past twenty years.

The causes of the popularity of Economics are stated with fair unanimity by various writers, though their respective importance is very differently estimated. In the first place, the very novelty of economic studies is itself in favour of their ardent prosecution. Till comparatively recently, it has been said till between 1870 and 1880, they were disregarded because unknown. Now they are seized, studied, and followed because they offer, or seem to offer, an explanation of the vast and complex economic condition which is in process of rapid evolution in this country—at once so great and so new. So, too, in England some half-century back or more the theories of the economists of that time were received by large numbers as an intellectual gospel. But in the next place the circumstances attending this 'novelty' of study have considerable consequences. That the study of Economics is a novel study is important, but it is of equal importance that it is novel at the present time and under present conditions. The American economists have not to shake off the half-uttered, half-silent opprobrium attached to their subject through the action of the more numerous though less conspicuous of their predecessors in their rigid adherence to incomplete or ill-founded theories. They are fortunate in entering upon their teaching at a time when the need of inductive inquiry and training is more fully recognised. This gives a more systematic aspect to the economic instruction demanded from them than was the case in England. In the third place, the campaign in favour of civil service and tariff reform has drawn a great deal of attention to those departments which deal with finance and the more prominent aspects of political life. Lastly, it is urged that the political eagerness which so largely affects the younger generation of Americans combines with the foregoing to crowd the economic lecture rooms with anxious and willing students. Economics is needed by politicians, and 'we are all politicians,' writes one professor; it is needed by journalists both because they are keen for political knowledge themselves and because they write for politicians.

The same causes which stimulate economic students have often led to its connection with political science, with history, and in some instances with general sociology.

Returns from several of the universities show the large number of students who attend economic lectures, and the comparatively large number who pass into advanced courses. The universities differ so much among themselves that no common standard of teaching exists. In some the elementary courses are very elementary, in others more thorough than might be concluded from the name. Thus at Harvard these include a study of Mill's 'Principles of Political Economy,' lectures on general theory, or on what is termed Descriptive Economics, including a survey of financial legislation; while in addition a course is provided on the Economic History of England and America since the Seven Years' War. In some cases a great part of the junior work consists in the use of text-books, and proceeds rather by class instruction and interrogation than by lecture. Turning to the consideration of the courses organised for the more advanced students, it is highly satisfactory to note the very considerable proportion which these form of the total number engaged in economic study. According to the information collected from various quarters, at Harvard they amount to some 38 per cent., at Columbia College to 41 per cent., at Cornell to 26 per cent. At some others they do not present so favourable an appearance, though at Michigan I am informed that the twenty returned as 'advanced' consist entirely of *very* advanced students, all the others being included under the heading of elementary. No doubt students described as advanced at one institution may not be so regarded at others, for, as has been already suggested, these vary very greatly as regards both their courses and the attainments of their students. With regard to the former, those provided at some of the better known and more highly developed and equipped universities afford a description of the nature of the training offered in the United States. At Harvard the advanced courses for the year 1892-93 are as follows:—

Full courses—

Economy Theory—Examination of Selections from leading writers.
The Principles of Sociology—Development of the Modern State and its Social Functions.
The Social and Economic Condition of Working Men in the United States and in other Countries.
The Economic History of Europe and America, to 1763.

Half courses—

History of Tariff Legislation in the United States.
Railway Transportation.
The Theory and Methods of Taxation.
History of Economic Theory down to Adam Smith.
History of Financial Legislation in the United States.

At Columbia College the courses are as follows:—

Elements of Political Economy.
Historical and Practical Economics.
History of Economic Theories.
Science of Finance.
Science of Statistics.
Railway Problems.
Financial History of the United States.
Tariff and Industrial History of the United States.
Communism and Socialism.
Taxation and Distribution.
Sociology.

At Cornell the lectures which succeed the purely elementary ones are not quite so full, but consist of courses on—

Economic Reforms.
Finance.
Economic Legislation.
Statistics.
Economic History.
Financial History of the United States.

There are few universities which do not offer some courses beyond these on elementary theory and history. As a rule, finance and some other branch of Applied Economics are added. Where graduate schools have been established, as, for instance, at Harvard and at Michigan, the study proceeds very much on the lines indicated above, so far as the former is concerned. At Michigan, the advanced courses are distinguished into intermediate and graduate. *Intermediate* courses treat of the following:—The Transportation Problem. Principles of the Science of Finance. Theory of Statistics. History and Principles of Currency and Banking. History of the Tariff in the United States. History and Theory of Land Tenure and Agrarian Movements. Industrial and Commercial Development of the United States. History and Theory of Socialism and Communism. History of Political Economy. *Graduate* courses:—Critical

Analysis of Economic Thought. Critical Examination of the Labour Problem and the Monopoly Problem.

Most universities have, in addition, established seminars, where study proceeds on the lines with which Continental students are familiar. Individual members, in most instances graduates, and all advanced students, undertake particular subjects, on which they prepare reports or treatises to be read and discussed at the weekly meeting. During their researches they are more or less under the direction of the professor or teacher who undertakes the courses in connection with the department of Economics under which their subject falls. At Yale there are two seminaries and one discussion society; at Columbia College there is one for students who have studied only one year, two (in Economics and Finance) for those who are more advanced. The value of the work produced differs, of course, with the character of the university. At Harvard and the other more highly developed universities it is naturally very high.

In certain other countries the attention given to the subject of Economics demands for different reasons less detailed notice. In some instances the resemblance to countries already described renders further description superfluous; in others the geographical limitations of the country, or the comparative absence of opportunities for such special branches of the higher education, necessitate a much slighter notice than that given to the foregoing countries.

In Spain the connection between economic and legal studies is very similar to that existing in Italy. Students of the first and second year attend courses in Economics and Finance, Statistics being apparently nowhere insisted upon. At some of the universities an attempt is made to supplement these elementary courses by conferences and by visits, both to industrial undertakings, as factories, mines, &c., and to financial establishments, as banks; while the introduction of sociological institutes or seminars is looked for at others, as, for instance, at Oviedo.

In Sweden 'there are two professors of Political Economy, one at the University of Upsala, one at the University of Lund, both belonging to the Faculty of Law, and teaching in addition to Political Economy some purely juridical subjects. There are also two professors in Politics and Statistics, one at Upsala, one at Lund, both belonging to the Faculty of Arts, and teaching at their discretion Public Law, either Swedish or foreign, and Statistics.' 'The two professors of Political Economy in the Faculty of Law have to prepare and examine all the students who go in for the State examinations for entrance to the different branches of the civil service. But as Political Economy possesses very little importance in any of the three forms of these examinations, as compared with Jurisprudence,' little stress is laid on its study in this faculty. Of the two other professors, one (at Upsala) lectures chiefly on Politics, the other on Statistics, both these studies being optional for the two Arts degrees. The theory of Political Economy is not taught. Seminar instruction is arranged to supplement that given in the lecture courses.

In Norway, at the University of Christiania, the system is nearly identical with that of Sweden. There, too, it is found that, owing to the complete subordination of Economics to Law, the knowledge required is elementary in character.

The same impulses which direct the attention of young Americans to the study of Economics are felt in Canada. At the University of

Toronto the importance attached to such studies is adequately shown by the large attendances present at the several courses. These courses are carefully arranged and graduated so as to furnish the student with a sound knowledge of the various branches of the subject, and to fit him to undertake, as he is expected to do in his latter years, research into some branch of economic fact.

In Switzerland, the position held by economic studies is, on the whole, at least as favourable as that in the southern countries of Germany. A knowledge of Economics is obligatory on those entering the legal profession, while, owing to the arrangements made, the duty of examining the candidates may, and in practice, I believe, does fall largely on the university professors. Moreover, in the university curricula, the place of Economics, so far as Berne is concerned, is very fortunate. True, the subject is optional, as indeed are all subjects for the doctorate, but it may be taken for either the legal or the philosophical doctorate (Dr. Juris or Dr. Phil.). At the Zürich Polytechnicon it is taught, being obligatory in some form or other for the diplomas of Forestry and Agriculture. In addition there is a fair voluntary attendance at these lectures. The system of instruction presents no features requiring particular notice. The chief courses are on National Economy and Finance, with the frequent addition of Practical Economics. These are supplemented by special courses at the option of the teacher, and by the seminar.

APPENDIX II.

On Economic Studies in France. *By* HENRY HIGGS.

Economic teaching in France, so far as it consists of lectures regularly delivered at the same place by the same person, is to be looked for in—

(i.) The *Collège de France*, Paris;
(ii.) The *Conservatoire des Arts et Métiers*, Paris;
(iii.) The *Université de France*, consisting of the aggregate of local 'universities,' or faculties officially recognised, in Paris and the provinces;
(iv.) The free or unofficial faculties and schools in Paris and the provinces, including all the Catholic 'universities' (which cannot come to terms with the State on the question of the faculty of theology), the *École Libre des Sciences Politiques*, Paris, and others.

A certain amount of economic instruction is also imparted in the *Écoles supérieures du Commerce*, generally endowed by the municipalities of commercial towns. Elementary notions of Economics are officially prescribed as part of the programme of elementary schools.

(i.) It is at the *Collège de France* that one expects to find leading teachers of Economics in France. The traditions of its chair (which was founded in 1830), and the authority vested in its occupants, added to the attractions of a scientific post in Paris, have been a sufficient inducement for the most eminent economists to offer themselves for appointment here. The stimulus of contact with growing, vigorous, and inquiring minds is not, however, afforded to the professors, and they have to fight against a tendency to fall into prosy sermons and easy repetitions of old theory. No fees are charged to the students, nor is any record kept of their names unless they wish to obtain certificates. The lectures are delivered twice a week (two on Economics by M. Leroy-Beaulieu, and two on Statistics by M. Levasseur), in the afternoons. The auditors are for the most part a casual collection of shifting persons, of whom many are foreigners passing through Paris, who attend once or twice out of curiosity to see the lecturer. There is no discussion either during or after the lectures. The professors are paid a fixed stipend by the State. They appear to regard their lectures in the main as vehicles for the dissemination of generally received economic theory. So far, however, as they employ their leisure in prosecuting original research, their stipends may be regarded as an endowment for the advancement of Economics. Their personal examples are stimulating. It would be difficult to mention two more active economists in Europe. But in their lectures they are perhaps too dogmatic to supply students with the zest of grappling with 'unsettled questions,' or with the incentive to enlarge, however little, the bounds of knowledge by pointing out to their hearers the frontiers of ignorance which are often in sight.

(ii.) The oldest chair of Political Economy is in the *Conservatoire des Arts et Métiers*, and was first filled, in 1819, by J. B. Say. The instruction now given here is of a more popular character, consisting of lectures addressed to the working classes at a late hour of the evening. M. Levasseur delivers a five-year cycle of about fifty lectures a year on Economics, and M. de Foville a four-year cycle on Industry and Statistics. There are on the average from 300 to 400 auditors. They pay no fees. The professors are appointed and paid by the Government.

(iii.) By a law passed in 1877 Economics was for the first time officially incorporated into the organisation of higher education in France, by being made an obligatory subject in the second year's studies of the faculties of law. Economics in France has, it is said, laboured under the disadvantage of offering no opening for a career. On the other hand, the youth of the country flock to the schools of law, for to lawyers all careers are open—politics, journalism, literature, education, legal practice, and many official appointments. The professor of Law is overworked, and the professor of Economics underworked. The faculty of Law, therefore, generally expects of its professor of Economics that he shall be able to help in legal instruction and examinations; and there has been a tendency to select a lawyer rather than an economist for these chairs. This reproach, however, is rapidly being removed, and the new professors of Economics are in many cases vigorous and promising in their proper spheres. Economics has recently been transferred from the second to the first year's programme. The law students are said to show a better intelligence of law now that they also study Economics. It can hardly yet be stated what effect this organisation will produce on Economics itself.

In addition to this obligatory study, Economics may be taken as one of the eight optional courses at a later period of preparation in the Law faculties. For this purpose there is generally a special course of lectures on Finance, in which financial legislation is a prominent topic; but the option in favour of Economics is not much exercised.

The professors and lecturers in Economics and (in italics) in Finance in the official faculties of Law are as follows:—

Paris . MM. Beauregard, *Alglave*, and *Ducrocq*; Fernand Faure (Statistics); Planiol (Industrial Legislation); Maroussem (Monographs).

Aix . .	M. Perreau.	*Lyons* . .	MM. Rougier, *Berthélémy*.
Bordeaux .	MM. St. Marc, *de Boeck*.	*Montpellier* .	MM. Gide, *Glaise*.
Caen . .	MM. Villey, *Lebret*.	*Nancy* . .	M. Garnier.
Dijon . .	MM. Mongin, *Lucas*.	*Poitiers* .	MM. Bussonnet, *Petit*.
Grenoble .	MM. Rambaud, *Wahl*.	*Rennes* .	MM. Turgeon, *Charreau*.
Lille . .	MM. Deschamps, *Artus*.	*Toulouse* .	M. Arnault.

There are also at Montpellier lectures on industrial legislation by *M. Laborde*.

(iv.) The position of the Catholic 'universities' has already been referred to. While following the lead of the State in associating Economics with Law, they have the advantage of recruiting among their students a large number of those who desire to enter the Church with a training in economic science as an aid to the study of social problems. The respective professors are MM. Jannet (Paris), Baugas (Angers), Béchaud (Lille), Rambaud (Lyons), and Peyron (Marseilles).

The *École Libre des Sciences Politiques*, Paris, directed by M. Boutmy, is perhaps the most hopeful academic institution in France for the promotion of economic study. Lectures are given by MM. Cheysson (Economics); Stourm, Dubois de Lestang, Plaffin, Courtin (Finance); Levasseur (Statistics); Dunoyer (History of Economics since Adam Smith); Arnauné (Foreign Trade and Customs Laws); Lévy (Banking); P. Leroy-Beaulieu (Colonial Systems); Paulet (Industrial Legislation); and Guieysse (Industrial Problems). In addition to these lectures, which are well attended by paying students, there are discussions and classes for original work on the seminar plan. Travelling scholarships are also given, and excellent work is done, to which the general scheme of instruction largely contributes. The primary function of the school is the thorough intellectual equipment of young officials for the State. Foreign languages, travel, and comparative study of laws and social institutions are encouraged, together with an intelligent interest in history and politics. The personal assistance rendered to individual students by the professors, the seminar, and the scholarships, the comprehensive breadth of view, and the rigid impartiality of this school are, as yet, unique in France.

Other economic lectures in Paris which require mention are those of M. Colson, at the *École Nationale des Ponts et Chaussées* (where the Government non-military engineers and road surveyors are trained), of M. Cheysson at the *École Nationale des Mines* (also under Government), of M. F. Passy at the *École des Hautes Études Commerciales* (endowed by the municipality), of M. Émile Chevallier, &c. Lectures (by M. Guérin) are organised by the *Société d'Économie Sociale*, founded by Le Play. M. Demolins, the leader of a secession from this school, also delivers a course of lectures. There is, on the whole, too much diffusion of separate economic lectures in Paris.

An impressive plea has lately been published by M. Chailley-Bert for the recognition of distinct economic faculties, and for such endowments as will spare professors from the need of spending their time and brains upon accessory sources of income.

APPENDIX III.

On the Condition of Economic Studies in the United Kingdom.

By E. C. K. GONNER.

Though the full extent of the disadvantages under which economic study in this country suffers can only be realised from a fairly detailed account of its position in the various universities and with relation to certain professions, it will not be out of place to preface this report with a few words as to their nature.

(*a*) In the first place it is a matter of serious concern that Economics is not regarded as a necessary part of any professional curriculum. This particular hardship, however, might be faced with comparative equanimity were there existent in this country, as for instance in the United States of America, a strong body of popular feeling in support of its study and its efficient teaching. But, despite frequent assertions to the contrary, I believe, and in this I shall have the concurrence of many colleagues engaged in teaching, that there is no such body of feeling. Its absence has been variously accounted for. To a great extent it is no doubt part of the legacy of distrust and misunderstanding due to the false view of Economics placed before a former generation, and it will probably be a long time before the popular conception of an economist as a compound of text-book theory and ignorance of fact can be entirely dispelled.

(*b*) Owing largely to the early prominence of the abstract school of economic thought in England, the position which the subject holds in the university curricula is far from satisfactory. It is often treated as a subject narrow in scope and subordinate—necessarily and naturally subordinate—to other subjects. But this is by no means the position which it should hold, and now that the importance of the studies of economic fact and administration is more clearly seen, the impossibility of effective teaching within the prescribed lines has become glaringly apparent. At present indeed English economic teaching is without a regular system. It is usually supposed that prescribed university courses should offer a means of systematic training in the various subjects, the pass courses of ordinary training, the honours courses of advanced and thorough training. So far as Economics is concerned, this is precisely what the universities do not provide. With some possible exception they offer at the present time little more than general opportunities of showing economic knowledge in examinations primarily devoted to other subjects.

In the United Kingdom the encouragement of the study of Economics rests entirely with educational bodies. So far as professional examinations and curricula are concerned it meets with almost universal neglect. This is wholly so with regard to the examinations qualifying for the practice of law, either as barrister or solicitor, and partly so in the case of the Civil Service Examinations. For these latter Economics may be taken up, as may almost any other subject included in the Sciences and Arts. It is not recognised, that is to say, as more cognate to the administrative callings for which these examinations qualify, than is chemistry, for instance ; indeed, in comparison with many of these other subjects it is at a discount owing to the smaller maximum of marks assigned to it. In other words, it is excluded from the legal curriculum ; in the Civil

Service Examinations it is an optional but not an important subject. Elementary Political Economy is one of the optional subjects in the examination for chartered accountants, and is obligatory on candidates for the voluntary examination recently instituted by the Institute of Bankers.

At the universities it receives an insufficient recognition in the degree courses, but as its position varies a great deal a brief summary of the usages of the various universities with regard to it may be given. Degrees are granted in England by the five Universities of Oxford, Cambridge, Durham, London, and Victoria; in Scotland by the Universities of Edinburgh, Glasgow, Aberdeen, and St. Andrews; in Ireland by Trinity College and the Royal University of Ireland.

ENGLAND.

At *Oxford* it is an optional subject, which may be taken up as one of the three selected subjects for the pass B.A. degree. As studied for this examination it is mainly elementary and largely theoretical, many of the questions relating to certain prescribed portions of the works of Adam Smith and Walker. To pass this examination, for which the yearly number of candidates presents an average of two hundred, demands commonsense and a fair general acquaintance with leading economic topics. A paper on Economics is included among those set in the Honour School of Modern History.

At *Cambridge* the position occupied by Economics in the university curricula is far more satisfactory. In some shape or other it forms part of three degree examinations. All candidates for the ordinary pass B.A., after passing the general examination, have to take up a special subject for their concluding study. Of these, sixteen in all, there are seven Arts special subjects, one of which is Economics. The special examination in Economics (Political Economy) consists of two parts, which may be taken at separate times:—

Part I.—Three papers.
  Two in General Economic Theory.
  One in Economic History.

Part II.—Three papers.
  Two in Taxation and Economic Functions of Government, with History of Trade and Finance, 1760–1860.
  One in General Theory of Law and Government.

In the Moral Science Tripos (Honour B.A.) there are six obligatory papers, two being assigned to Political Economy, while in addition advanced Political Economy ranks as one of the specified subjects, two of which must be passed in by a candidate desirous of being classed. Lastly, in the Historical Tripos (Honour B.A.), one paper is in Economic History, the paper on general History of England also being supposed to require some economic knowledge. Further, candidates who desire it may take Political Economy and Theory of Government with International Law as an alternative to the study of a second special subject. Of these three examinations, those which seem most satisfactory, so far as Economics is concerned, are the special for the pass B.A., which embraces at once the four important branches of administrative, theoretical, historical, and financial Economics, and the Moral Science Tripos so far as that part is concerned which affects students taking up advanced Economics.

In the *University of Durham*, in addition to the obligatory subjects, two optional subjects have to be chosen by candidates for the degree. These are selected out of a number of subjects, of which Economics is one. The knowledge required is not of an advanced nature.

In the *University of London* Economics holds no position but the somewhat unfortunate one of a subject for candidates proceeding from the B.A. to the M.A. degree in Moral Science, a position which at once restricts the number of students likely to study it, and prevents its study from extending much beyond the knowledge of general theory. It is not a subject, either optional or obligatory, at any other examination.

In the *Victoria University* Economics, comprising Political Economy and Economic History, forms one of the twelve optional subjects, of which two have to be selected for the final year of study by candidates for the pass B.A. degree, the two other subjects being more or less restricted. Economic Theory or History may also be taken in conjunction with Modern History as one subject by candidates who wish, for instance, to take Modern History but not Ancient History. As, however, nearly all the other subjects are, with some difference of standard or period, subjects at the intermediate or second-year examination, in some instances compulsory, and again in certain cases subjects at the final examination, the study of Economics, involving as it does the entry of the student upon a wholly new subject during his final year, is naturally discouraged. Further, Economic Theory (Political Economy), like any other Arts or Science subject, may, by permission, be substituted for one of the two selected general subjects, Ethics or Modern History, at the intermediate stage of the Law degree (LL.B.). A course of lectures in Political Economy has to be attended by candidates for the Honours degree in History. It is not a subject in the examination,

SCOTLAND.

By the regulations of the Commission applicable to all Scotch Universities, Economics holds a twofold position.

(*a*) With regard to the ordinary M.A. examination, it is one of the three optional subjects which have to be selected out of the usual Arts and Science subjects. In all, seven subjects must be taken, but of these four are more or less prescribed. The course which must be attended consists of at least 100 lectures.

(*b*) It is further a compulsory subject for the first examination for the Agricultural B.Sc. In this case the knowledge required is much slighter, and naturally much more closely related to rural economy.

IRELAND.

At *Trinity College* Economics is part of one of the seven groups in which the Honour degree may be taken, the other subjects in this group being History and Law. All candidates for the Law degree must be graduates in Arts, but not necessarily graduates in Honours, or if in

Honours, in this particular group. It is also included among the options for the pass degree.

In the *Royal University of Ireland* Economics (Political Economy) is an alternative with Ethics in one of the three groups, one of which must be passed by candidates for the ordinary pass B.A. In the examinations for the Honour degree (B.A.) it, with Civil and Constitutional History and General Jurisprudence, constitutes one of the six groups open to the student. It holds a very similar position in the examination for the M.A. degree.

The foregoing account shows clearly how little opportunity is given for the systematic study of Economics as a preliminary to degree examination, and especially in the case of Honours. It is certainly very unfortunate that an able student anxious to graduate in Honours is almost precluded from devoting a large amount of attention to the study of Economics.

In face of this tacit discouragement, so far as examinations are concerned, the provision for teaching made in many places by colleges and universities is almost a matter for surprise. At both Cambridge and Oxford it is satisfactory in all but one respect. It is varied and comprehensive, but—and this is a matter of regret—it is not sufficiently systematic. At each of these universities there is a professor engaged in active teaching, while other lecture courses are provided by college lecturers. At the universities and colleges in the rest of England the provision for teaching is of necessity less complete. At those best equipped, instruction in Economics depends on the energy and vigour of a single teacher, supplemented, perhaps, by an *occasional* course of lectures by some other economist; while at the rest, if taught at all, it is attached to the duties of a teacher principally engaged in, and probably principally interested in, teaching some other subject, for, as a general rule, the teaching of Economics in conjunction with some other subject has meant little more than that the teacher of some other subject has had to give a course of lectures on General Economics. At two of the three colleges of the Victoria University Economics has separate teachers—at Liverpool one holding the rank of professor, at Manchester one holding that of a lecturer. At Leeds, on the other hand, there is no teacher of Economics. At the other university colleges in England the two London colleges possess each a professor, though the professor at King's College delivers Economic lectures only during the six winter months. At the University College, Nottingham, Economic lectures are delivered by a professor at the same time engaged in teaching history and literature. The other colleges (Birmingham, Bristol, Sheffield, and Newcastle) at present make no provision for teaching a subject which they find so discounted as a subject for examination.

In Wales two of the University Colleges (Aberystwith and Cardiff) have made some sort of provision for Economic teaching by the appointment of lecturers in History and Political Economy; while at Bangor Economics is tacked on to the duties of the Professor of Moral Philosophy.

In Scotland there is a fully instituted chair of Political Economy at the University of Edinburgh, and measures are in progress for the endowment of a Professorship at Glasgow, where the Economic work has recently been performed by a lecturer acting as assistant to the Professor of Moral

Philosophy. At St. Andrews a yearly course of lectures is delivered by the Professor of Moral Philosophy.

In Ireland, at Trinity College, Dublin, there is a Professorship of Economics. At the Queen's Colleges of Belfast, Cork, and Galway this teaching is combined with that of Jurisprudence, and limited to a very short portion of the year.

Owing to the great differences existing between the courses delivered at the various institutions, and the entirely diverse character of the respective audiences, it is impossible to give any satisfactory statistics of attendance. From most quarters come complaints. Indeed, with the two possible exceptions of Oxford and Cambridge, it is difficult to imagine a more complete indifference to the *scientific study* of Economics than that displayed at the present time.

In addition to lectures, more informal instruction is often imparted to more advanced students, but the formation of a seminar in Economics has been undertaken but seldom, if at all. That this is due not to lack of will on the part of the teachers in those colleges where Economic teaching is entrusted to a separate teacher, but mainly to the singular deficiency in advanced or even moderately advanced students, is shown by the readiness with which individual instruction, often involving much sacrifice of time, is given to such students when they do present themselves. Such an institution can be successfully introduced only when Economic studies are so recognised as to be able to attract the abler students in a university or college.

Attempts to develop popular Economic instruction by means of evening classes, and separate courses of lectures, have been made by the university colleges and other institutions, and by the Societies for the Extension of University Teaching; and at some of the former particular attention has been paid to the Economic teaching, noticeably at Owens College, Manchester, and University College, Liverpool. The class of students attracted to these lectures may be spoken of very favourably. From the reports and information supplied by the Societies, it would seem that though the attendance at Economic courses, when given, is good, the demand for them is not very great. The interest shown in the subject in some one or other of its branches is said to be reviving—certainly to be greater than it was some few years ago. There has been a decided increase in the demand for lectures on Economics, and subjects partially economic, during the last two years.

Economic studies in England require at the present time organisation and encouragement. As to the ability of English Economists and the quality of their contributions there can be no doubt; but, when compared with Continental countries, England is sadly lacking in the number of Economic students. Where they have many, she has few. As has been said, this is largely due to the unfortunate position to which Economics has been relegated in many universities, and its neglect so far as professional callings are concerned. On the other hand, the revival of interest in Economic matters, so abundantly manifested, makes it exceedingly desirable to provide means and opportunities for sound scientific training.

Methods of Determining the Dryness of Steam.—Report of the Committee, consisting of Sir F. J. BRAMWELL, *Bart.* (*Chairman*), Professor T. H. BEARE, Mr. JEREMIAH HEAD, Professor A. B. W. KENNEDY, Professor OSBORNE REYNOLDS, Mr. MAIR RUMLEY, Mr. C. I. WILSON, *and* Professor W. C. UNWIN (*Secretary*).

THE determination of the quality of steam, or its wetness, has come to be of very great importance both in boiler trials and engine trials. It was in the classical researches of G. A. Hirn at Logelbach in Alsace in 1854–57, and in subsequent experiments by MM. Grostête, Hallauer, and Leloutre, and other members of the Société Industrielle of Mulhouse, that the great importance of the action of water in the steam-engine cylinder was first clearly recognised. It was perceived that the water present in the cylinder, and which may amount to 50 per cent. of the steam introduced, was due to three distinct causes: (*a*) initial wetness of the steam; (*b*) condensation in the mass of steam due to adiabatic expansion; (*c*) the action of the cylinder wall. An accurate discussion of the results of an engine test is impossible if the initial condition of the steam is unknown, both because the total heat per pound of steam received by the engine depends on its dryness, and because water introduced with the steam increases the prejudicial action of the cylinder wall.

In boiler tests the evaporative efficiency is measured in pounds of water converted into steam per pound of coal. But if part of the feed water supplied leaves the boiler as water entrained in the steam, the real evaporation is less than the apparent evaporation. The entrained water must be allowed for in estimating the evaporative efficiency of the boiler. Further, a boiler which supplies wet steam is a bad boiler, because wet steam is prejudicial to the efficiency of the engine, and it should be one object of a boiler trial to determine whether the steam is of good quality.

The earliest attempts to determine the amount of moisture in steam which have come to our knowledge were made during some boiler trials by a committee of the Société Industrielle of Mulhouse.[1] This committee tried three methods: 1. *A Method of Separation.*—The whole of the steam was taken through a spare boiler, without fire, in the expectation that the moisture would be deposited. The increase of water in the spare boiler during a trial was measured, and that part of the increase due to condensation by radiation was determined by a special experiment. 2. *A Condensing Method suggested by Hirn.*—Some of the steam from a boiler under trial was condensed and its total heat determined. By comparing the total heat per pound with that of dry saturated steam the amount of moisture was ascertained. 3. *A Chemical Method.*—Salt was introduced into the boiler, and the diminution of saltness of the boiler water during a test determined. It was assumed that moisture in the steam would be of the same saltness as the boiler water, and therefore the amount of salt removed measured the wetness of the steam. In these early trials only the second method appeared to give reasonable results. But the committee did not place full reliance on any of the methods tried.

Origin of the Water Suspended or Entrained in Steam.—There are three sources of the water found in steam:—

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[1] 'Report of MM. E. Burnat and E. Dubied,' *Bulletin de la Société Industrielle de Mulhouse*, 1859.

(1) By ebullition boiler water is projected into the steam space. Part falls back, but part is carried on in the steam current. The extent to which wetness may be thus produced depends on the activity of the ebullition, the area of the water surface, the volume of the steam space, the position of the steam valve, the density of the steam, and other circumstances. In certain conditions of the boiler water, it *foams*, and the steam space is filled with vesicles. Under such circumstances the mechanically produced priming may be excessively severe.

As to priming of this kind some observations of Mr. Thornycroft on a boiler with glass ends are very instructive.[1] He states that 'waters which cause priming on boiling produce foam, consisting of a mass of bubbles of various sizes. Water which is very bad produces bubbles so durable as to remain a considerable time without breaking, and by them the steam space of a boiler may be entirely filled. So soon as this takes place, instead of simply steam leaving the boiler, the discharge consists of foam, which is broken up in its rapid passage through the steam pipe.' With pure water, steam retains no film of liquid for sufficient time to be seen.

(2) The steam in the boiler is subject to variations of pressure. Bubbles formed under water rise to a region of less pressure. Fluctuations of pressure arise from the intermittent demand for steam. During expansions water must be formed as mist throughout the mass of the steam. It is difficult, however, to suppose that any great quantity of moisture is thus produced.

(3) The steam in the steam space of the boiler, and when flowing through the steam pipes, loses heat by radiation from the boiler roof and the surfaces of the pipes. To this must correspond condensation of part of the steam. Probably in some cases very considerable amounts of moisture are produced in this way.

Methods of Determining the Wetness of Steam.—Very different methods have been tried by different observers to determine the amount of moisture in steam. Some method is required sufficiently accurate for practical purposes, and not involving excessively delicate measurements or complicated apparatus. It is proposed to describe all the methods which have been tried which seem at all likely to be useful, and finally to give the results of some comparative trials made for the committee which throw light on their relative trustworthiness.

I. *Weighing Method.*—A method of direct weighing of a known volume of a sample of steam has been proposed by Guzzi[2] and Knight.[3] A copper globe is used as a measuring vessel, which is placed in a receiver connected with the boiler or steam pipe. After filling, it is taken out and weighed. Let V be the volume of the globe, w the weight of wet steam in it. Let $(1-x)w$ be the moisture and xw the steam in the globe, and let v be the volume in cubic feet per pound of dry steam in the same conditions of pressure and temperature. Then

$$(1-x)w=w-\frac{V}{v}$$

$$x=V/vw$$

The method is one obviously of excessive difficulty.

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[1] 'Circulation in the Thornycroft Water Tube Boiler,' *Trans. Inst. Naval Architects*, 1894.

[2] *Revue Industrielle*, 1878, p. 102.

[3] *Journal of the Franklin Institute*, 1877, p. 358.

II. *Separating Method.*—Attempts have been made to ascertain the amount of moisture in steam by measuring the quantity of water trapped in a separator, between the boiler and engine, through which the whole of the steam passed. Probably such separators are too small relatively to the amount of steam flowing through them to detain the whole of the moisture. Mr. G. A. Barrus, in using a small separator in connection with a superheating calorimeter, noticed that very nearly the whole of the moisture was caught by the separator. In that case the quantity of steam passing through the separator is small.[1] More recently Professor Carpenter, of Cornell University, has brought out a form of separating calorimeter of small size which can be applied almost anywhere on a steam pipe or boiler, and which can be used with very great facility.

The separating calorimeter (fig. 1) consists of a vessel, A, about 12 in. × 3 in., consisting of an inner chamber and a jacket. The steam from the steam pipe, S, passes first into the inner chamber, where the moisture is separated, and thence into the outer chamber. The separating chamber is consequently almost perfectly protected from radiation. As the water accumulates in the inner chamber its level is shown by a gauge glass, g, and the amount can be read off on a scale. A very small orifice at the bottom of the outer chamber regulates the amount of steam discharged. The steam as it escapes passes through a flexible tube to a simple form of condenser, C. The increase of weight of the condenser in any given interval of time is noted, and the amount of water deposited in the same time in the separator. If x is the dryness fraction of the steam, w the weight of water caught in the separator, and W the weight of steam condensed,

$$x = \frac{W}{W + w}$$

The scale on the separator is graduated to $\frac{1}{100}$ths of a pound. There is also a gauge glass and scale on the condenser, graduated to read pounds and tenths at a temperature of 110° F. But as the variation of volume of the water with temperature affects the readings considerably, it is best to weigh the condenser, or, at any rate, to determine a correction of the scale for temperature. Professor Carpenter states that the dryness of the steam after passing the separator was tested in the laboratories of Sibley College by several observers, and with steam carrying from $\frac{1}{4}$ per cent. to 60 per cent. of moisture. In every case the separation of the water from the steam was complete and perfect.[2] Other tests have been made with moderately dry steam, using the separating and throttling calorimeter simultaneously, and the results were practically identical. The instrument is very simple to use, and requires no pressure gauges or thermometers.

III. *Condensing Method.*—Suppose a known weight of the steam condensed and its total heat determined. By comparing this with the total heat of an equal weight of dry saturated steam, according to Regnault's Tables, the amount of moisture in the steam can be determined.

The apparatus designed and used by Hirn in the Mulhouse trials in 1859 (fig. 2) is, so far as we know, the most convenient and perfect apparatus hitherto used in trials of this method. It consists of an iron vessel, C, about one foot in diameter, furnished with a loose cover. This

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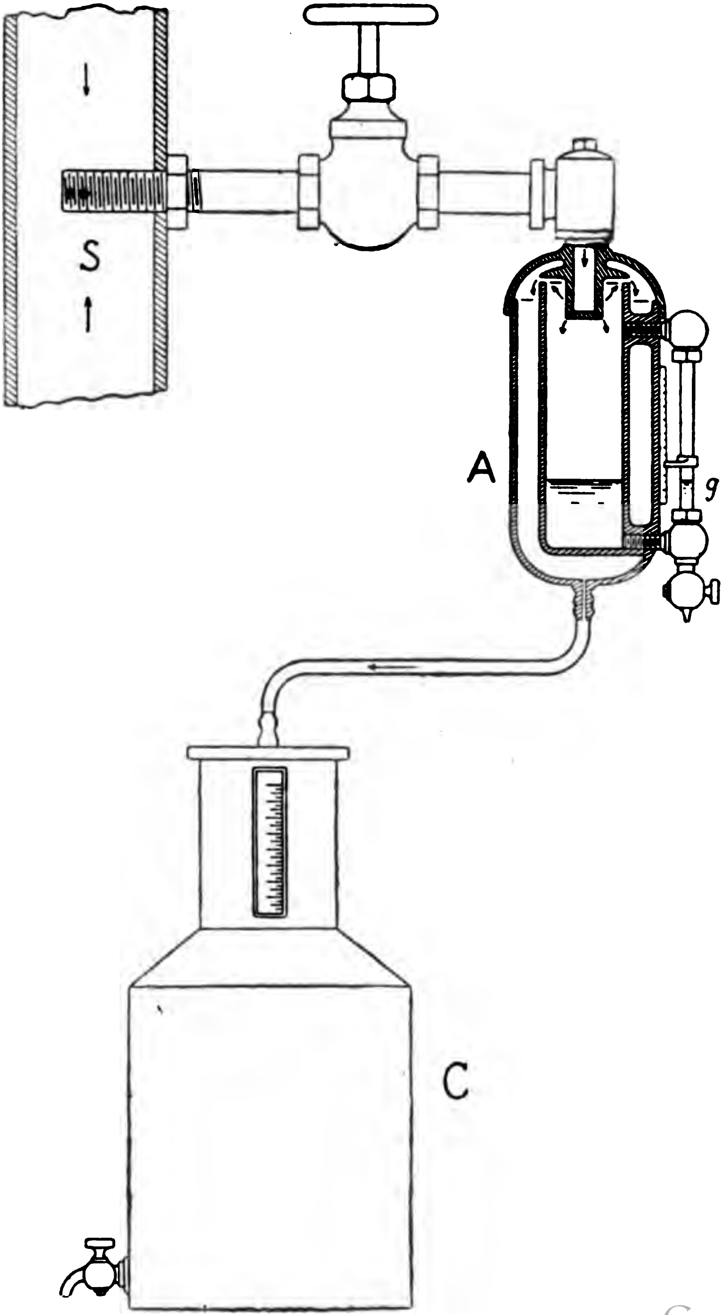
[1] See Barrus, *Boiler Tests*, Boston, U.S.A., 1891, p. 258.

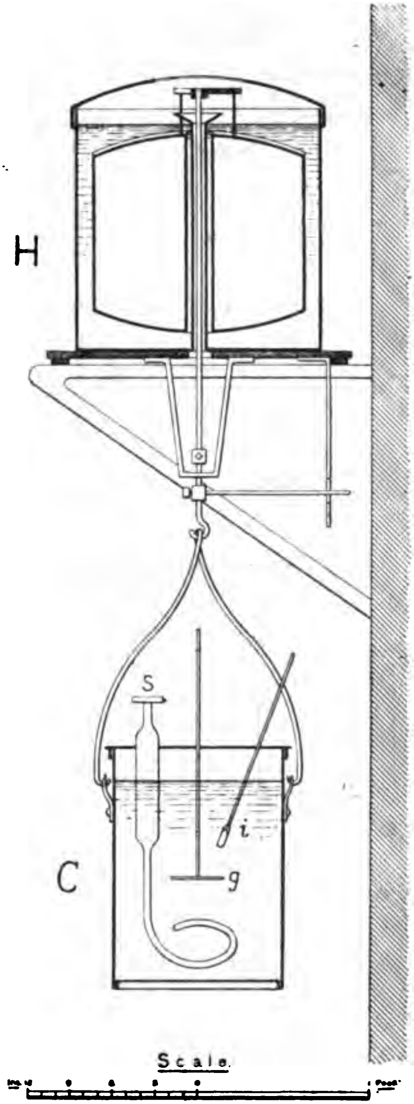
[2] See *Experimental Engineering*, by R. C. Carpenter, New York, 1892, p. 400.

FIG. 1.



is the condenser. A small pipe and cock in the steam pipe deliver steam, through a small orifice near the steam pipe, into the pipe S. An agitator, *g*, and a sensitive thermometer, *i*, are provided. The condenser is suspended from a hydrostat, H, which permits extremely accurate weighing of the amount of steam condensed.

FIG. 2.



Let x be the dryness fraction of the steam, w the increase of weight of the calorimeter. Then the condenser has received xw lb. of dry steam and $(1-x)w$ lb. of water at the steam temperature. Let W be the weight of water initially in the condenser plus the equivalent reckoned as water of the condenser itself. Let t be the temperature of the steam, and i and f the initial and final temperatures of the condenser water. Then

$$xw(1116-0{\cdot}71t)+w(t-f)=W(f-i)$$
$$x=\frac{W(f-i)-w(t-f)}{w(1116-0{\cdot}71t)}$$

To arrive at satisfactory results the temperatures must be read to $\frac{1}{10}$ degree at least, and the weight of steam condensed determined very accurately. Further, it is desirable that the temperature i should be about as much below the temperature of the place where the test is made as the temperature f is above it. A correction is easily made for the small fall of temperature by radiation during the time the agitator is used to secure uniformity of temperature. Suppose the agitator is used for two minutes, and the temperature f then noted. The temperature is again noted two minutes later. The small observed fall is the loss in the interval by radiation, and is added to the observed temperature f as a correction. In the Mulhouse experiments the initial and final temperatures of the condenser were generally about 60° and 110° F. The following table gives the results of the Mulhouse tests in 1859. They were made very carefully, and Hirn himself directed the tests.

The committee at Mulhouse, in discussing these results, point out their variability, and remark that a mean of numerous observations should be taken. This is probably true when the test is made on a small scale. In Mr. Willans's tests one hundredweight of steam was condensed in each test, and this gives what is virtually a mean of numerous smaller tests. In the case of Trial 23, the Mulhouse Committee thought that the calorimeter underestimated the amount of priming water.

About 1860, Joule used a calorimeter very similar to the above, in order to determine the total heat of steam and verify Regnault's results. The paper describing the experiments[1] is interesting as showing that fairly accurate results can be obtained by this method, used on a small scale, when the observer is sufficiently skilful. The amount of steam condensed was only from 8,700 to 14,100 grains in each test. Temperatures were read to three decimal places. The weight of water in the condenser was about 140,000 grains. The steam flowed into the condenser for two minutes. The steam must have been almost perfectly dry, as the following (mean) results show :—

Pressure of Steam	Total Heat	
In. of Mercury	Observed	By Regnault's Tables
37·25	638·43	638·77
57·52	644·77	642·87
111·58	655·45	649·60

The method has been often used in determining the wetness of steam in boiler trials, but very often the arrangements have been so rough that no reliance can be placed on the results. A calorimeter of this

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[1] *The Scientific Papers of J. P. Joule*, vol. i. p. 482.

BOILER TRIALS AT MULHOUSE.

Trials with Hirn's Calorimeter on the Quantity of Water entrained in Steam.

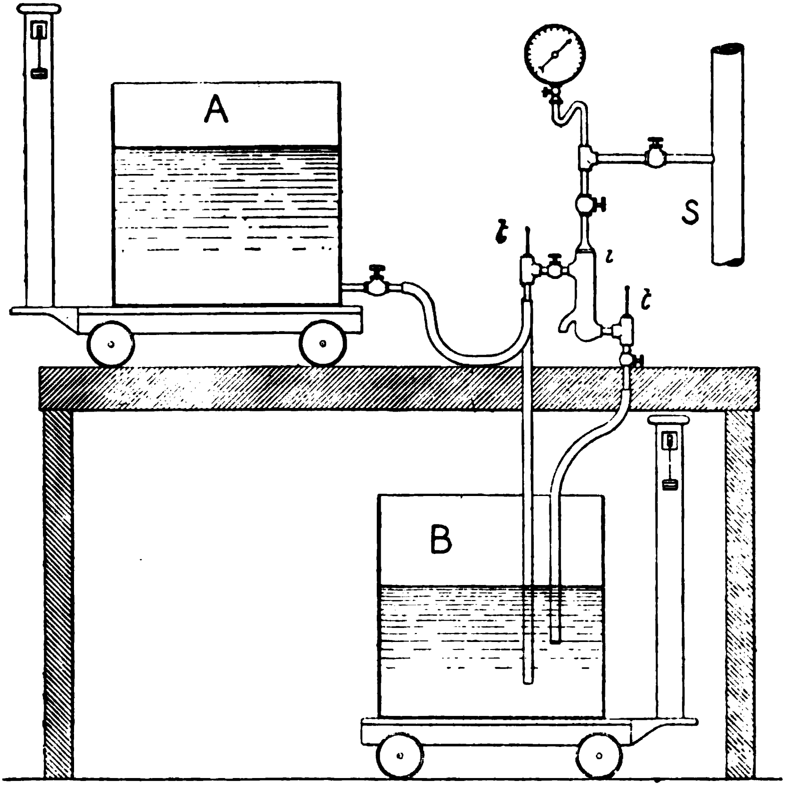
No. of Trial	Date 1859	Boiler	Level of Water, Mm.	Pressure in Boiler in Atm.	Weight of Water entrained, Grams	Weight of Water entrained, per cent.	Remarks
1	Sept. 6	Prouvost	Nearly constant	4·0	—	16·0	The water levels are the heights of the water in the boiler above bottom of gauge-glass. Trials 1 to 6 with steam taken from top of steam pipe.
2	6			4·7	—	3·3	
3	6			4·75	—	3·4	
4	7			4·4	—	3·5	
5	8			4·15	--	3·4	
6	16			4·5	—	3·7	
7	Oct. 5	Molinos and Pronnier	—	4·6	—	4·6	In Trials 7 to 14 steam was taken from top of steam pipe. In Trials 15, 17, 25, steam was taken from the outside of a bend in the steam pipe.
8	6		—	4·8	37	4·2	
9	6		—	5·2	54·7	7·1	
10	8		+28	4·75	19·8	2·2	
11	8		0	4·8	20·1	1·9	
12	8		+15	5·2	26·8	2·4	
13	8		—	5·2	37·8	4·8	
14	11		−15	4·75	20·8	2·5	
15	11		−15	4·75	43·5	6·8	
16	11		−15	4·75	120·4	12·5	
17	Oct. 12	Molinos and Pronnier	−25	5·1	40·5	4·4	Trials 14, 16, 18, 24, with steam from the underside of the same bend. Trials 14 and 15, 16 and 17, 24 and 25, were made at the same time. In Trials 27 and 28 steam was taken by a pipe opening at the centre of the steam pipe. In Trial 23 a great deal of water was carried by the steam and discharged by the relief valves.
18	12		−15	4·6	17·3	2·0	
19	12		−35	5·0	34·6	4·2	
20	12		−10	4·7	35·8	3·7	
21	12		+100	5·0	56·4	6·4	
22	13		+210	5·3	46·1	4·9	
23	13		+250	5·25	111·8	11·8	
24	13		+190	5·4	16·8	2·0	
25	13		+220	5·1	25·0	2·8	
26	13		+180	5·1	37·0	4·4	
27	14		—	5·1	42·2	3·6	
28	14		+85	5·0	35·4	1·6	
29	Oct. 17	Zambaux	+70	4·4	60·9	6·9	Trials 29 and 31 with the same arrangement as 27 and 28.
30	17		+75	4·3	10·6	1·4	
31	18		+50	4·6	38·4	3·7	

Omitting Trial 23, the mean amount of water carried by the steam was 4·4 per cent.

kind is called in America a barrel calorimeter. The barrel test is carried out thus. An ordinary oil barrel is used, fitted with an outlet valve. A set of tests are made following each other rapidly, and an average of the results is taken. The barrel is filled and a trial made, the results of which are discarded. The object seems to be to heat up portions of the apparatus and the barrel itself. The barrel is then refilled, weighed, and the temperature of the water taken. A steam pipe connected to the boiler is then blown through to warm it, and a movable pipe is attached leading to the barrel. The steam valve is then opened and the steam condensed in the barrel, till the temperature has risen to about 110° F. The valve is shut, the movable pipe removed, the water stirred, and the barrel again weighed and its temperature taken. It is obvious that the proceeding is a very rough one. Losses of heat by radiation, &c., tend to make the observed total heat too small, and therefore the moisture in the steam too large. On the other hand, evaporation from the barrel tends to make an error of the opposite kind. It is known that in using this method in a rough way negative results are sometimes obtained.

Mr. P. W. Willans used this method also to determine the wetness of the steam in his engine trials.[1] Mr. Willans used a very large condensing tank weighing full about 3 tons, and placed on the platform of a weighing machine. The tank was first balanced so that the weighing machine lever just rose. Then a standard hundredweight was placed on the platform of the machine, and the poise adjusted so that the lever again just rose. The hundredweight was then removed, the temperature of the condenser was noted, and steam condensed in the tank till the lever rose (making an electric signal). The steam at that moment was

FIG. 3.



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[1] 'Economy Trials of a Non-condensing Steam Engine,' by P. W. Willans, *Proc. Inst. Civil Engineers*, vol. xciii. p. 23.

turned off, and the tank contained exactly one hundredweight of condensed steam. The condensing water was then stirred and the temperature taken. The thermometers were sensitive (1° C. corresponded to 1 in. in some of them), and they were carefully compared with standard thermometers. A very small radiation correction was made. The value of the dryness fraction found on different days was ·9996, ·9638, ·9949, ·9646, ·9976, ·9893, 1·0072, 1·0048, ·9987. The mean of all is 0·9911, showing an average of about 1 per cent. of moisture in the steam. In spite of the large scale on which the experiment was tried and the care taken, the results are rather discrepant, and two of them give values which it would seem must be erroneous.

IV. *Continuous Condensing Method.*—The difficulties of the ordinary condensing method have led Mr. Barrus, Mr. Hoadley, and other observers to adopt a process of continuous steady condensation. The steam may be condensed (a) in the condensing water, or (β) in a surface condenser. The first method[1] may be carried out by the apparatus shown in fig. 3. Steam passes from the steam pipe, S, to a small injector, *i*. The condensing water is drawn from the tank A, and the mixed water and condensed steam are discharged into the tank B. If W_1 is the decrease of weight of A in any interval, and W_2 the increase of weight of B, then $w=W_2-W_1$ is the weight of steam condensed. Thermometers t, t, give the temperatures of the water entering, and mixed steam and water leaving the injector. Let t_1, t_2 be these temperatures, and t the temperature of the steam. Then, if x is the dryness fraction,

$$w\{(t-t_2)+xL\}=W_1(t_2-t_1)$$

$$x=\frac{\frac{W_1}{w}(t_2-t_1)+t_2-t}{L}$$

$$=\frac{\frac{W_1}{w}(t_2-t_1)+t_2-t}{1116-0{\cdot}71t}$$

Mr. Barrus has used a surface condenser (fig. 4), consisting merely of a short vertical pipe in a vessel through which cooling water circulates. The condenser is supplied with cooling water at a fixed rate of flow. Then, as the condensing surface is constant, the rate of condensation is constant, and the rise of temperature of the cooling water is constant. Condensation is carried on for any convenient period, and the condensed steam run off for weighing. Simultaneously a series of readings are taken of the temperature of the water entering and leaving the condenser, and of the condensed steam. The radiation correction can be determined by observing the fall of temperature in the condenser when the supply of steam and cooling water is stopped.[2] The continuous condensing method seems likely to be more accurate than the ordinary method, but the arrangements are more complicated.

V. *Method by Superheating.*—Mr. G. H. Barrus about 1890 devised a calorimeter in which the steam to be tested passed through a chamber jacketed with superheated steam. The steam was thus dried and superheated. The quantity of heat required was inferred from the fall of temperature of the superheated steam. The orifices of the inner steam pipe and outer jacket were equal, so that the same weight of steam passed through each. Hence no weighing was necessary. If t_1 t_2 are the temperatures of the superheated steam entering and leaving the jacket, and t_3 t_4 the temperatures of the steam entering and leaving the inner chamber, then the superheated steam in the jacket has lost t_1-t_2 degrees of temperature, and the sample steam has been dried and superheated t_4-t_3 degrees. If x is the dryness fraction and L the latent heat of the steam in the inner chamber,

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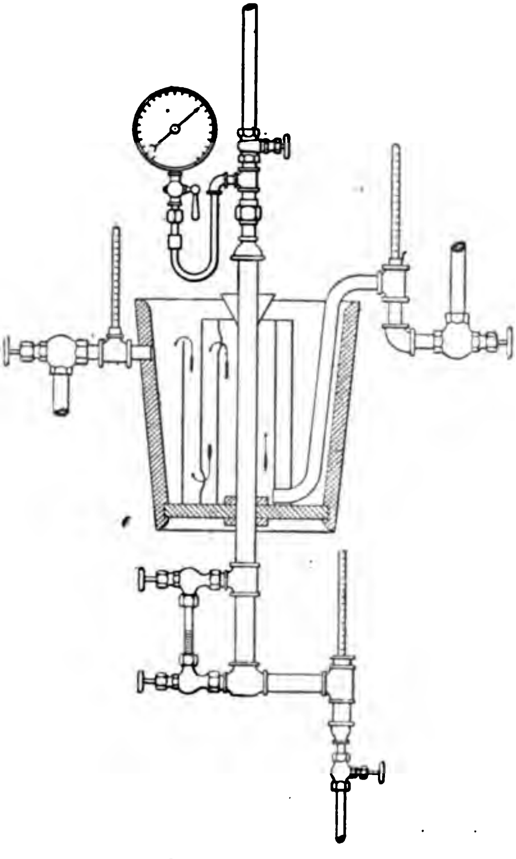
[1] Carpenter, *Experimental Engineering*, p. 375.

[2] See Peabody, *Thermodynamics of the Steam Engine*, p. 232; Carpenter, *Experimental Engineering*, p. 380.

FIG. 4.



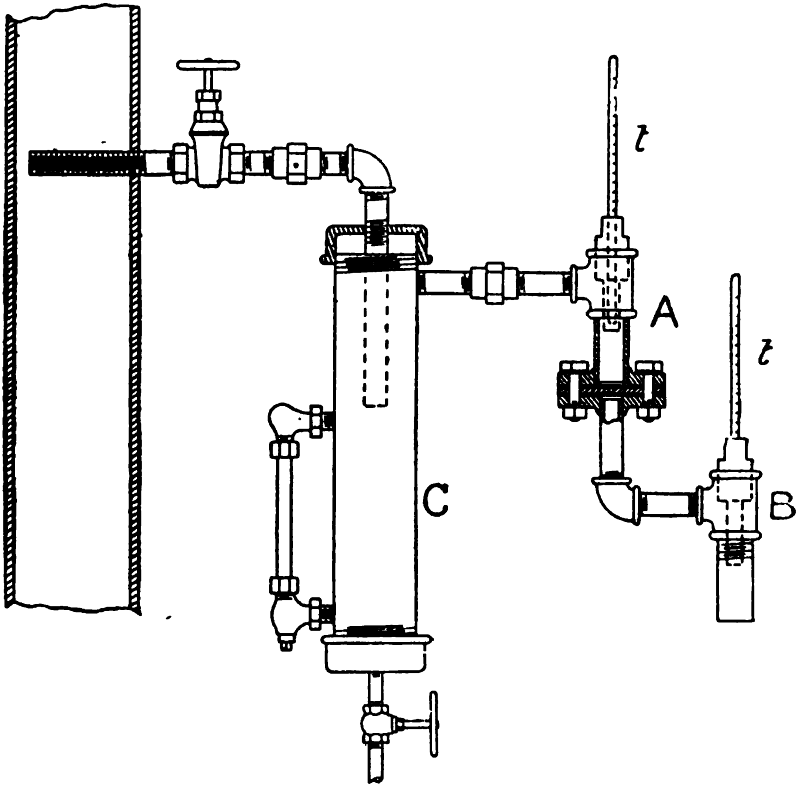
$$0{\cdot}48(t_1-t_2-l)=\mathrm{L}(1-x)+0{\cdot}48(t_4-t_3)$$
$$1-x=0{\cdot}48(t_1-t_2-l-t_4+t_3)\div\mathrm{L}$$

l is a small correction for radiation. Only four thermometer readings are necessary for a determination. The calorimeter is only suitable for nearly dry steam, and appears to be superseded by the simpler throttling and separating calorimeters. A description will be found in 'Boiler Tests,' 1894.

Barrus, Boston, 1891, p. 18, and in 'Experimental Engineering,' Carpenter, p. 386.

VI. *The Wire-drawing Method.*—This was first proposed by Professor Peabody. Mr. Barrus and others have devised modified forms of the apparatus. It depends on the principle that slightly moist steam is superheated by wire drawing. Fig. 5 shows Mr. Barrus's arrangement[1] of the apparatus. The steam passes from a chamber A to a chamber B through a very small aperture ($\frac{1}{16}$ inch in diameter). The full steam pressure is in A, and the pressure in B differs little from atmospheric pressure. Thermometers *t*, *t*, give the temperatures of the chambers. Let t_1 t_2 be the temperatures of the steam before and after wire drawing, and t_3 the temperature of saturated steam corresponding to the pressure in B. $t_2 - t_3$ is the amount of superheating of the steam in B.

Fig. 5.



Let h_1, L_1 be the liquid heat and latent heat of steam at t_1; h_3, L_3, corresponding quantities for steam at t_3.

$$h_1 + xL_1 = h_3 + L_3 + 0{\cdot}48(t_2 - t_3)$$

$$x = \frac{h_3 - h_1 + L_3 + 0{\cdot}48(t_2 - t_3)}{L_1}$$

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[1] See *A Universal Steam Calorimeter.* By G. H. Barrus, Amer. Soc. Mech. Engineers, 1890.

Or taking the specific heat of water constant :—

$$x=\frac{t_3-t_1+\mathrm{L}_3+0{\cdot}48(t_2-t_3)}{\mathrm{L}_1}$$

$$=\frac{1116-t_1-0{\cdot}19t_3+0{\cdot}48t_2}{1116-0{\cdot}71t_1}$$

No weighing is required, and temperatures only have to be observed. The apparatus must be in operation for twenty to thirty minutes before observations are commenced. Then observations may be begun and continued for as long a period as is desired. It is not a mere small sample of steam, therefore, which is observed, but a considerable quantity taken from the steam pipe at a uniform rate. The observations are as simple as possible, and the apparatus is used with the greatest facility. Presently some tests will be given tending to show that the instrument is very trustworthy.

Suppose the steam is initially quite dry. Then $x=1$ in the formula above.

$$h_1+\mathrm{L}_1=x_3+\mathrm{L}_3+0{\cdot}48(t_2-t_3)$$

$$t_2=0{\cdot}604t_1+0{\cdot}395t_3$$

From the small excess of pressure over atmospheric pressure t_3 is about 214°. Then

$$t_2=0{\cdot}604t_1+84{\cdot}5.$$

This may be termed the normal temperature in the chamber B for dry steam. In proportion as the temperature falls below this the steam is initially moist. If it contains initially more than a certain amount of moisture, the temperature in the chamber falls to 214° or below it, and no calculation of the dryness is possible.

If $t_2=220°$ and $t_3=214°$ are taken as the limiting values for which the instrument can safely be used, there being then 6° of superheating in B, then

$$x_{\mathrm{min}}=\frac{1181-t_1}{1116-0{\cdot}71t_1}$$

and

$$(1-x)_{\mathrm{max}}=\frac{0{\cdot}29t_1-65}{1116-0{\cdot}71t_1}$$

give the minimum initial dryness or maximum amount of initial moisture in steam for which the apparatus is suitable.

$t_1=$	Greatest initial moisture per cent.
250°	0·80
300	2·44
350	4·21
400	6·13

VII. *Combined Separating and Wire-drawing Method.*—To extend the usefulness of the wire-drawing method Mr. Barrus added a separator (C, fig. 5). The steam first passes through the separator, leaving most of its moisture, and the remainder is measured by a wire-drawing calorimeter. When thus arranged the use of the instrument is much more complicated, as the amount of steam flowing through and the amount of moisture separated must be weighed. A condenser must therefore be used, at any rate occasionally, to determine the amount of steam flowing in a given time. Assuming the orifice to remain unchanged, a formula can be found for the weight of steam discharged per minute at any given pressure.

VIII. *Superheating by Addition of Heat.*—A method has been proposed by Mr. W. R. Cummins,[1] in which a vessel of constant volume is used, completely surrounded by a steam jacket. Steam is at first blown through both jacket and vessel till there is a fair sample of the steam to be tested in both. Next the jacket and vessel are cut off from the steam pipe and from each other. The steam in the jacket is then heated by compression (by a steam compressing pump) or by heating. The simultaneous rise of pressure and temperature in the vessel containing the sample of steam are observed. While moisture is evaporating the relation of pressure and temperature will follow Regnault's law. From the moment when superheating begins the pressure will increase much less rapidly with the temperature. Let t_1 be the temperature of the sample of steam initially, t_2 the temperature at which superheating is observed to begin, v_1 v_2 the corresponding specific volumes of dry saturated steam, x the initial dryness of the steam, V the volume of the vessel, and w the weight in pounds of steam admitted. Then

$$V = xv_1w = v_2w$$

$$x = \frac{v_2}{v_1}$$

where the specific volumes v_2v_1 can be calculated from the observed temperatures t_2 t_1. The method is quite accurate in principle, but it would involve considerable skill to carry it out accurately, and it does not appear to have been actually tried.

IX. *Chemical Methods.*—These suppose that some soluble salt is added to the boiler water so as to form a solution of known strength, and that of all the feed supplied to the boiler part is evaporated and flows away as steam, part as priming water. The former removes no salt; the latter is of the saltness of the water then in the boiler. Hence, either the decrease of saltness of the boiler water or the amount of salt present in the steam can be used in determining the amount of priming water in the steam. Most commonly table salt ($NaCl$) has been used because the amount in solution can be easily determined by the nitrate of silver method. In other cases sulphate of soda has been used, the sulphuric acid being determined by precipitating with chloride of barium. It is convenient to describe three variations in the way in which the chemical method is applied.

(a) *Decrease of Saltness of the Boiler Water measured.*—Salt is introduced with the feed till the boiler water contains 1 or 1½ per cent. of salt. Then, during a test in which the amount of feed is measured, a sample of the boiler water is drawn off at the beginning and end of the test. Care must be taken that the level of the water in the boiler (as shown by the gauge glass) is exactly the same when the two samples are taken. Let W be the weight of water in the boiler, and s_1 s_2 the percentage of salt in the two samples. The amount of salt removed from the boiler during the test is $W(s_1 - s_2)/100$. Let w be the amount of feed supplied, and x the dryness fraction of the steam. Then xw lb. of pure steam are generated, and $(1-x)w$ lb. of priming water carried over. The mean saltness of the priming water is $(s_1+s_2)/2$. Hence

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[1] *Trans. North-east Coast Inst. of Engineers and Shipbuilders*, 1893.

$$\frac{(1-x)w}{100}\ \frac{s_1+s_2}{2}=\frac{W}{100}(s_1-s_2)$$

$$x=1-\frac{2W}{w}\ \frac{s_1-s_2}{s_1+s_2}$$

The method deals with the whole amount of steam produced, and not with mere samples of it. On the other hand, the disadvantages of the method are: (1) It measures only priming water mechanically projected into and carried by the steam, and not moistness produced in other ways. (2) Great exactness of analysis is necessary, the difference of saltness being a small quantity. (3) The feed, being continuously supplied at one part of the boiler, tends to produce, in spite of the circulation, a non-uniform distribution of saltness throughout the mass of water in the boiler. If the saltness is not uniform, the difference of saltness of the samples gives a quite erroneous result. If there is salt in the feed water, it can be allowed for. This method was first used at Mulhouse in 1859; much later it was revived, and is often called Brauer's method.

(β) *Percentage of Salt in the Steam determined.*—At intervals during a test, samples of the boiler water are taken, and at the same time some steam is condensed in a small surface condenser. Equal quantities of the water samples are mixed together, and also equal quantities of the condensed steam. Let s_1 be the percentage of salt in the averaged sample of boiler water, and s_2 that in the averaged sample of condensed steam. If x is the dryness fraction of the steam, each pound contains x lb. of steam and $1-x$ lb. of water of the saltness of the boiler water.

$$(1-x)\,s_1=s_2$$

$$x=1-\frac{s_1}{s_2}$$

The disadvantages of this method are (1) that very small portions of the steam are tested, and, as the mechanical action producing priming is probably irregular, it is very uncertain whether they fairly represent the average condition of the steam; (2) the accurate determination of s_1 can only be made if the boiler water is uniformly salt; (3) the amount of salt in the steam is very small compared with that in the boiler water, so that the accurate determination of s_2 is difficult.

(γ) *Escher's Method.*—A quite different method of considerable interest has been proposed by Mr. R. Escher, of Zurich.[1] Mr. Escher considered the case of a boiler fed with impure water. Of the salts in solution some are thrown down as incrustation, others remain in solution. In the boiler water during working there is a steady concentration of these soluble salts, which tends towards a fixed limit. At this limit the priming removes as much salt in the form of concentrated boiler water as the feed brings in.

Let s be the saltness of the feed water in pounds per pound of water, and k, the saltness at any given time of the boiler water. Then each pound of steam removes $(1-x)\,k$ lb. of salt, while each pound of feed introduces s lb. of salt. In steady working when the limit is reached

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[1] *Civilingenieur*, 1879, p. 51.

$$(1-x)\,k=s$$

$$x=1-\frac{s}{k}$$

Let $k/s=c$, the ratio of concentration of the boiler water. Then, for example, if the boiler water contains twenty times as much salt as the feed, $x=1-\frac{1}{20}=0{\cdot}95$, or the steam contains 5 per cent. of priming water. The method assumes that the feed contains a definite percentage of easily soluble salt, and that the trial has continued till the maximum concentration is reached.

But if the boiler is freshly filled it may be a long time before the limiting condition is reached. Let W be the quantity of water in the boiler in pounds, and F the quantity of feed per unit of time. Let k be now the saltness of the boiler water at t from the beginning of the test. In a short interval, dt, the quantity of salt $\mathrm{F}s\,dt$ enters the boiler with the feed, and the quantity $\mathrm{F}(1-x)k\,dt$ is carried away in the priming water. The increase of salt in the boiler is therefore

$$\mathrm{W}dk=\mathrm{F}\left\{s\,dt-(1-x)\,k\,dt\right\}.$$

Let $\mathrm{W}/\mathrm{F}=a$. Then

$$a\,dk+(1-x)\,k\,dt-s\,dt=0.$$

Integration gives

$$k=\frac{s}{1-x}+\frac{\mathrm{C}}{e^{\frac{1+x}{a}t}}$$

The constant of integration is obtained by putting $k=s$ when $t=0$. Let also $\frac{1+x}{a}t=n$. Then

$$s=\frac{s}{1-x}+\mathrm{C}$$

$$k=\frac{s}{1-x}\left(1-\frac{x}{e^n}\right)$$

$$c=\frac{k}{s}=\frac{1}{1-x}\left(1-\frac{x}{e^n}\right)$$

From this equation, c being ascertained by analysis of the boiler water, x can be determined at any period of the test. As the equation is not easily solved x may be approximated to thus. If c is the concentration after t hours' working, a first approximation to x is

$$x_1=1-c.$$

Put this in the expression above for c; a value c_1 will be obtained which would be the concentration in the time t, if c were the limiting concentration. Then assume

$$\frac{c}{c_1}=\frac{c_{\mathrm{max}}}{c}$$

$$c_{\mathrm{max}}=\frac{c^2}{c_1}$$

This is an approximate value of the maximum concentration in unlimited time. A second approximation to x is

$$x_2 = 1 - \frac{c_1}{c^2}$$

Mr. Escher has not directly suggested how his method could be used in the case of a boiler fed with pure feed water, or, say, with water containing too small an amount of chloride to give a sufficiently rapid concentration. But it might easily be applied by pumping in with the feed, at intervals of an hour, a known quantity, w, of a saturated salt solution. The quantity w might be so arranged that the concentration at the end of the test was such that the boiler water contained about 1 per cent. of salt. A preliminary assumption as to the amount of priming would have to be made in settling what quantity of salt to introduce.

The salt method by measuring the decrease of saltness of the boiler water was first used at Mulhouse in 1859. In the trials then it failed to give satisfactory results. In some of the tests an apparent increase of saltness of the boiler water was found, which must have been due to the saltness being ununiformly distributed in the boiler. At Düsseldorf in 1880 the method of measuring the salt in the steam was tried, sulphate of soda being used.[1] Ten samples of boiler water and condensed steam were taken in each test. The results were discrepant, giving 0·21 to 9 per cent. of moisture in the steam in different tests.

Use of the Salt Method in the Berlin Trials of Portable Engines in 1883.—The most careful tests by the salt method which have been found are some made by Dr. Bunte in Munich, in some trials of portable engines under the direction of a commission appointed by the German Government.[2] In these tests both the decrease of saltness of the boiler water and the amount of salt in samples of condensed steam were determined. They throw some light, therefore, on the relative trustworthiness of the two proceedings.

Concentrated salt solution was introduced into the boilers before beginning a test till the boiler water contained 1 to 1½ per cent. of salt. At the beginning of each trial, and with the water at normal level in the gauge glass, a sample of boiler water was taken; at some intermediate times, and at the end of the trial, similar samples were taken. The boiler water was taken from a gauge cock. To prevent evaporation in taking the sample it was drawn off through an india-rubber tube into a vessel containing 500 c.c. of cold distilled water. Exactly 500 c.c. of boiler water were drawn off, so that the sample had half the saltness of the boiler water. The chlorine was determined by a nitrate of silver solution containing 10 per cent. of normal solution, with the addition of chromate solution as an indicator. For the steam samples the steam was taken from a cylinder or valve-chest cock. From 200 to 1,000 grams were condensed at intervals of about an hour.

In Trial I., on the Dolberg Portable, the boiler-water samples showed the same saltness at the beginning and end of the test. Intermediate samples showed very slight variations, attributed by Dr. Bunte to variations of water level in the boiler. In five samples of condensed steam an addition of 0·2 to 0·3 c.c. of silver solution gave a colour reaction. Dr. Bunte calculates that the priming must have been less than 0·1 per cent. Both methods, therefore, showed that there was practically no priming. Identically similar results were obtained in trials of four other boilers. But in one trial there was considerable priming. In Trial IV., on Siegel's Portable, the sample of boiler water taken at the beginning showed 199 c.c. of 10 per cent. of normal salt solution, and that at the end 191 c.c. per 100 c.c. This corresponds to a loss of 4 per cent. of the salt in the boiler, or to 1·7 per cent. of priming. In the steam tests different samples yielded 24·3, 20·3, 6·8, 4·0, 0·3, 0·2, 0·3, 25·5, and 7·3 c.c. of 10 per cent. of normal salt solution per 100 c.c. of condensed steam. After thoroughly cleansing the apparatus by blowing through, 2,000 grams of steam were condensed, and gave 9 c.c. per 100 c.c. The amount of salt in the steam was therefore extraordinarily variable. The highest result, 25·5 c.c. per 100 c.c., corresponds to 12·8 per cent. of priming. Dr. Bunte thinks that foaming occurred.

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[1] *Untersuchungen von Dampfmaschinen u.s.w. der Gewerbe-Ausstellung in Düsseldorf*, 1880 (Aachen, 1881), p. 13.

[2] Report by F. Schotte, *Civilingenieur*, 1884.

It will be seen that in most cases the salt test fails to indicate any appreciable priming. It must be inferred that the mechanical mixture of boiler water with the steam is ordinarily an action of insignificant importance. In one trial where there was great priming, shown by the working of the engine as well as by the salt test, the results are extremely discrepant, and apparently Dr. Bunte thinks that the real amount of priming was greater than the salt tests indicate.

The salt test was used in some tests of boilers at the Frankfort Exhibition, in 1891, by a committee presided over by Dr. Schröter.[1] The tests lasted eight days for each boiler. Salt was fed into the boiler till the boiler water contained about 1½ per cent. After the boiler had been working a day, two samples were taken, one of the boiler water from near the evaporating surface, one from the nearest water separator in the steam pipe. The samples were drawn off through a cooling coil to prevent evaporation. The amount of salt in the samples was determined by the nitrate of silver test, and also that in the feed supplied to the boilers. The following table gives the results:—

Determination of Priming by Salt Test in Trials at the Frankfort Exhibition, 1891.

Name of Boiler	Feed Water used	Salt in Boiler Water, per cent.	Salt in Water from Steam Pipe, per cent.	Salt in Feed Water, per cent.	Moisture in the Steam, per cent.
1. Essen Cornish . . .	Ordinary Water Co.	1·524	0·00116	0·00146	0·076
2. Dortmund Water Tube .	Purified	1·229	0·00138	0·00195	0·112
3. Ratingen „ .	Ordinary	1·146	0·00155	0·00148	0·135
4. Kaiserslautern „ .	Purified	1·442	0·00122	0·00193	0·085
6. Nürnberg „ .	Ordinary	1·610	0·00246	0·00164	0·151

These results are given chiefly to confirm the general result shown in nearly all experiments—namely, that the amount of priming estimated from a salt test is an insignificant percentage.

Comparison of the Salt Methods with other Methods.—It is clear that the general result obtained when the salt test has been used is that in ordinary cases there is very little moisture in the steam. Some trials made lately by Professors Kennedy and Unwin gave the same result. On the other hand, some trials simultaneously with the salt method and one of the other methods, such as the wire-drawing or separating method, have given this result: that the moisture in the steam indicated by the salt method was only about one-tenth as great as that shown by the other methods, and that not in steam taken from a steam pipe at a distance from the boiler, but in steam taken directly out of the boiler itself.

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[1] *Engineer*, June 8, 1894.

It is clear that the salt test can only indicate boiler water mechanically mixed with the steam by ebullition, not moisture produced in other ways. It might be expected, therefore, that the salt method would give a larger dryness fraction than other methods. Whether the great difference is entirely attributable to this cause, or in part to inherent difficulties in the salt method, cannot at present be ascertained. It would rather seem that the Escher method, which apparently has never been tried, would give the best results, if used in a case where the trial extended over a week or more.

A subordinate question is this. Some engineers have thought that the salt method was specially suitable for boiler trials because it gave directly what may be called the mechanical priming, although other methods were more suitable for engine trials where what is wanted is a knowledge of the absolute quality of the steam. This view seems to be founded on a misapprehension. In determining the efficiency of a boiler it is necessary to know how much of the feed leaves the boiler as steam and how much as water. If, in steam taken directly from the boiler, there is more moisture than corresponds to mechanical priming, that is as much a deduction from the evaporation of the boiler as if it were mechanical priming. The product of the boiler is so much wet steam, and the value of this steam depends on its dryness. The total heat utilised depends on the dryness. It is not at all important how the moisture came into the steam provided it is there. The only point to attend to in a boiler trial is that the steam tested should be taken directly from the boiler, and not from a steam pipe in which condensation due to radiation may have been going on. It is equally desirable that in an engine test the steam should be taken from the steam pipe very near to the engine.

TESTS TO DETERMINE THE RELATIVE TRUSTWORTHINESS OF DIFFERENT METHODS.

Test of the Wire-drawing Calorimeter.—The instrument tried was one received direct from Mr. Barrus. It seemed extremely desirable to get some kind of absolute test of the trustworthiness of this instrument, as it is much the simplest to use for nearly dry steam. Especially it seemed desirable to ascertain whether any correction for radiation or other loss of heat would be necessary. This can only be tested by using steam of known condition. The direction given in the instructions accompanying the instrument is to test it with the steam from a boiler not doing much work, the steam being then *assumed* to be dry saturated steam. But this is inconclusive.

To test this instrument, a small superheater was constructed, heated by a row of gas jets. Then there is definitely superheated steam in both chambers of the instrument. Let t_1' be the temperature in the first chamber, t_2' the temperature in the second chamber after wire-drawing. Apart from any loss by radiation, and assuming that the kinetic energy due to passage through the orifice is reconverted by friction into heat, the difference of temperature in the two chambers can be calculated. Let p_1 be the pressure in the first chamber, and t_1 the corresponding temperature of saturated steam; p_2 the pressure in the second chamber, and t_2 the corresponding temperature. Since the total heat per pound is the same in both chambers,

$$1082+0\cdot305t_1+0\cdot48(t_1'-t_1)=1082+0\cdot305t_2+0\cdot48(t_2'-t_2)$$
$$t_1'-t_2'=0\cdot3646(t_1-t_2).$$

In the following experiment the pressure in the second chamber was slightly greater than atmospheric pressure, and the corresponding temperature was 215°. Putting in this value

$$t_1'-t_2'=0\cdot3646t_1-78\cdot4.$$

Test of the Barrus Wire-drawing Calorimeter at the Central Technical College with Superheated Steam.—The steam was taken from a Babcock Wilcox boiler, and the engine was running. Steam valve opened at $2^h\ 49^m$, and gas jets of superheater lighted at $3^h\ 1^m$. Barometer 30·02 =14·75 lb. per sq. in. Pressures taken by a Schaffer and Budenberg gauge.

Time	Pressure by Gauge, lb. per sq. in.	Absolute Pressure, lb. per sq. in.	Saturation Temperature due to Pressure in First Chamber	Observed Temperature in First Chamber	Observed Temperature in Second Chamber	Observed $t_1'-t_2'$	Calculated $t_1'-t_2'$
h. m.			t_1	t_1'	t_2'		
3 32½	54	68·75	301·5	324	292	32	31·6
3 35	54	68·75	301·5	323·5	292	31·5	31·6
3 37½	54·5	69·25	302·0	324	292	32	31·7
3 40	54·5	69·25	302·0	325	294	31	31·7
3 45	54	68·75	301·5	324·5	295	29·5	31·6
3 47½	54	68·75	301·5	324	295	29	31·6
3 50	54·5	69·25	302·0	325·5	296	29·5	31·7
3 52½	54	68·75	301·5	325·5	296·5	29	31·6
3 55	53·5	68·25	301·0	326	297	29	31·4
3 57½	54	68·75	301·5	327	298	29	31·6
4 0	56	70·75	303·4	323	291	32	32·2
4 2½	56·5	71·25	303·9	322	288	34	32·4
4 5	54·5	69·25	302·0	325	291	34	31·7
4 7½	54·5	69·25	302·0	329·5	298	31·5	31·7
4 10	54	68·75	301·5	332	302	30	31·6
4 12½	54	68·75	301·5	334	304·5	29·5	31·6
Means .	—	—	301·9	325·9	295·1	30·78	31·45

The mean superheat in the first chamber was 24°. That in the second chamber 80°·1. There could be no doubt therefore as to the quality of the steam. The observed difference of temperature $t_1'-t_2'$ was remarkably constant, and the differences from the calculated values are not great. The mean difference of the observed and calculated values of $t_1'-t_2'$ is only 0·67. Necessarily the common pressure gauge readings are only approximate, and the difference is less than that which may be due to unavoidable inaccuracy in reading the pressure gauge. Since in ordinary use about 20° fall of the temperature t_2' corresponds to 1 per cent. of moisture in the steam, it appears that the calculated value of t_2' for dry steam is practically exact. Other experiments (though not over any great range of pressures) have been made. So far as they have gone, they confirm this result. Hence it appears that no correction of the theoretical calculation is necessary to obtain practical accuracy, and that the assumption that all the kinetic energy at the orifice reappears as heat is practically true.

In fig. 6 the temperature curves for the experiment above have been plotted. The saturation temperature t_1, due to the steam pressure, calculated from the pressure-gauge readings, and the actual temperature of the superheated steam t_{s1} are shown by the two upper lines. The temperature of the superheated steam in the second chamber t_{s2} is shown by a full line, and the calculated value of t_{s2} by a dotted line. The thermometer being in an iron tube necessarily lags a little behind the temperature in the chamber.

Test of a combined Separating and Wire-drawing Calorimeter by Mr. Barrus.—A very careful test is given by Mr. Barrus in his paper,[1] in which the steam passing through the instrument was condensed in a surface condenser and measured. Pairs of trials were made under identical conditions; in one the separator was in use, and in the other the separator was shut off. Each trial lasted usually an hour, sometimes two hours.

Pairs of Trials in one of which most of the Moisture was trapped in the Separator, and in the other the whole measured by Wire-drawing or Heat Gauge.

No.	Temperature by upper Thermometer	Temperature by lower Thermometer	Weight of Steam condensed in Surface Condenser per hour	Weight of Water from Separator per hour	Total Weight of Steam used per hour	Moisture calculated from Separator	Moisture calculated from Heat Gauge	Dryness of Steam	Total Moisture
	t_1	t_2	Lb.	Lb.	Lb.	Per cent.	Per cent.	x	Per cent.
1	312·4	265·4	53·87	0·644	54·51	1·18	0·40	·984	1·58
	312·2	239·6	53·89		53·89		1·80	·982	1·80
2	312·5	267·0	53·58	0·684	54·26	1·26	0·30	·984	1·56
	313·8	241·4	54·97		54·97		1·70	·983	1·70
3	313·6	266·4	53·91	1·284	55·19	2·33	0·40	·973	2·73
	313·1	225·0	54·40		54·40		2·60	·974	2·60
4	314·1	267·2	54·50	1·350	55·85	2·42	0·40	·972	2·82
	314·1	223·9	55·32		55·32		2·80	·972	2·80
5	314·3	267·9	55·00	1·309	56·31	2·33	0·40	·973	2·73
	314·3	227·1	55·82		55·82		2·60	·974	2·60

Mr. Barrus has used these results in an attempt to calculate a value for the specific heat of superheated steam, and gets values ranging from

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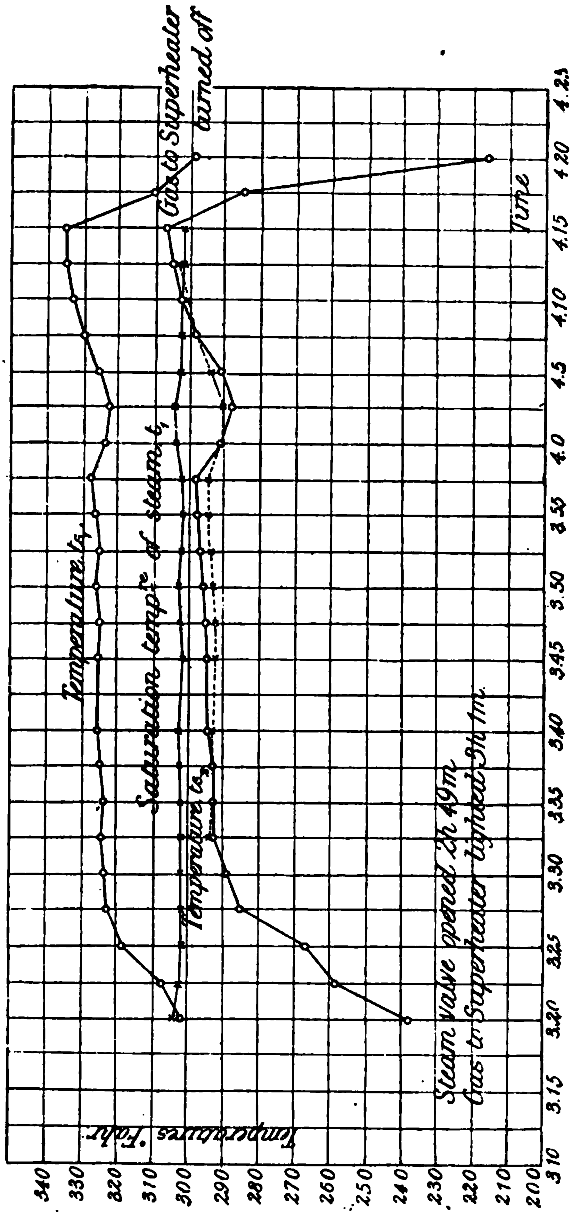
[1] Amer. Soc. Mechan. Engineers, 1890.

0·415 to 0·519, the mean value being 0·475, almost exactly the value generally assumed. It is hardly to be expected that experiments of this

FIG. 6.—Barrus Calorimeter using superheated steam at the Central Technical College, May 21, 1894.



kind are accurate enough to prove that the specific heat varies. On the other hand, Mr. Barrus has neglected to calculate the dryness fraction of the steam, and so has missed the striking evidence these results afford to the general accuracy of the instrument. The separator was not a very perfect one, and allowed about 0·4 per cent. of moisture to pass. But the separator results cannot be much wrong, for they are measured results depending on no assumed constants. The error in calculating the 0·4 per cent. passing the separator cannot be large enough to much affect the total result. On the other hand, the calculation from the heat gauge when the separator was cut out, which depends on the assumed value 0·48 of the specific heat and on the theory of the instrument, agrees strikingly with the separator results.

Test of Wire-drawing and Separating Calorimeter combined.—The following tests have been arranged to determine how far it is true, as stated by Carpenter, that a separator traps the whole of the moisture, even with very moist steam. The Barrus calorimeter was used with its drip box or separator. The amount of water deposited in the drip box was measured. Observations also were taken of the temperatures in the two chambers of the wire-drawing part of the instrument. Let t_1 t_2 be the temperatures in the first and second chambers of the wire-drawing part, t_3 the saturation temperature of steam in the second chamber calculated from the pressure. Then, from the formula given above,

$$x = \frac{1116 - t_1 - 0·19t_3 + 0·48t_2}{1116 - 0·71t_1}$$

The dryness in each experiment has been calculated by this formula for the steam passing from the drip box into the wire-drawing part.

Tests of Barrus Calorimeter with Separator attached at the Central Technical College.

Date	Time	t_1	t_2	t_3	x	Per cent. of Moisture trapped in Separator
	h. m. s.					
Nov. 27, 1893 .	4 23 30 4 27 45	294·5	256·2	215	·996	9
	4 27 45 4 32 15	292·5	257·0	215	·998	9
	4 32 15 4 37 15	289·0	257·0	215	·998	9
March 15, 1894 .	11 9 0 11 37 30	290·5	254·9	215	·997	5
	11 51 0 12 21 0	286·4	251·5	215	·996	5·7
March 28 . .	1 2 40 1 11 52	298·0	262·0	215	·997	4·4
Mean . .	—	—	—	—	·997	—

It will be seen that, although the steam entered the separator with more than 4·4 to 9 per cent. of moisture, the steam passing through the wire-drawing part had only from 0·4 to 0·2 per cent. of moisture. The mean dryness fraction of the steam passing to the second chamber in the six tests was 0·997, so that the error of using the separator without the wire-drawing part would generally, for practical purposes, lead to an error of no great importance, at any rate, when the steam had initially more than 1 per cent. of moisture. Further, the separator on the Barrus calorimeter is not quite so well arranged as that of the Carpenter calorimeter. The steam leaving the latter is no doubt drier than that leaving the separator of the Barrus calorimeter.

Test of a Carpenter separating Calorimeter, showing the Influence of Radiation from the Steam Pipe in producing Moisture in Steam.—The Barrus calorimeter and Carpenter calorimeter were fixed side by side for comparative tests. A branch pipe 30 feet long brought the steam from the main steam pipe, which delivered steam to the engine. This pipe was well clothed with Keenan's composition. The engine was running, so that there was a considerable flow of steam along the main steam pipe.

Two pairs of tests were made. In one the Carpenter calorimeter alone was used, and the flow of steam along the 30-foot branch pipe was comparatively slow. In the other pair, steam was flowing through the Barrus calorimeter also. As this uses twice as much steam as the Carpenter, the rate of flow was about three times greater than in the first pair of tests.

Test with Carpenter separating Calorimeter at the Central Technical College, March 28, 1894.

No.	Duration Mins.	Rise of Temperature of Condenser	Steam condensed in lb.	Water trapped in Separator	Per cent. of Moisture in Steam	Absolute Steam Pressure, lb. per sq. in.	—
1	4·833	21°·7	1·15	0·20	14·82	67	No steam flowing through Barrus
2	5·217	25°·8	1·36	0·20	12·82	72	
				Mean .	13·82		
3	6·60	32°·6	1·77	0·08	4·33	72	Steam flowing through Barrus
4	8·80	39°·5	2·19	0·08	3·52	68	
				Mean .	3·93		

The only difference in these two sets of experiments was that the rate of flow along the branch steam pipe was different. In the first set the mean moisture was 13·82 per cent., in the second set 3·93 per cent., being greater when the steam current was slower. The difference is due to condensation in the steam pipe. The result is important as showing how large the proportionate condensation may be, even in a well-clothed steam pipe, when the rate of flow is small, and also how important it is, in using calorimeters of this kind, which take only a small quantity of steam, to place them closely adjacent to the engine or boiler tested.

Simultaneous Wire-drawing and Salt Test on a Babcock Boiler at the Central Technical College.—Steam was taken by a short pipe clothed with felt from the casting carrying the safety valve at the top of the boiler. This pipe branched to the Barrus calorimeter and to a worm in a cold-water tank, closely adjacent to each other. The following table gives the Barrus calorimeter results in full to show the consistency of the determinations :—

Test with a Barrus Wire-drawing Calorimeter, June 5, 1894.

Steam valve opened at 11h. 25m. A.M. Barometer, 29·88 in. = 14·68 lb. per sq. inch. Pressure in second chamber, about 4 in. of water, or ·14 lb. per sq. in. Temperature of saturated steam corresponding to pressure in second chamber taken at $t_2 = 213°$.

Time	Pressure by Gauge on Boiler, lb. per sq. in.	Temperature of Steam, t_1	Temperature after Wire-drawing, t_2	Dryness Fraction of Steam, x	Per cent. of Moisture in Steam.
11.55 A.M.	58	301	241	·986	1·4
57½	56	300	240	·986	1·4
12.0	56	298	236	·985	1·5
2½ P.M.	56	298	240	·987	1·3
5	57	298·5	237·5	·986	1·4
7½	59	298	238	·986	1·4
10	59	300	240·5	·987	1·3
12½	60	300·5	242	·987	1·3
15	60	300·5	242	·987	1·3
17½	59	300	241	·987	1·3
20	58·5	300	240	·987	1·3
23	58	300	242	·988	1·2
25	57·5	300	240	·987	1·3
27½	57·5	299	241	·987	1·3
32½	59	299·5	242·5	·988	1·2
35	59	300	243·5	·989	1·1
37½	59	300	244	·989	1·1
40	59	300	244	·989	1·1
42½	59	300	244	·989	1·1
45	58	300	242	·988	1·2
47½	59	300	244	·989	1·1
50	57·5	300	244	·989	1·1
52½	56	299	243	·988	1·2
55	56	298	243	·988	1·2
57½	56	298	243	·988	1·2
1.0	57·5	299	243·5	·988	1·2
2½	59	300	244	·989	1·1
5	58	300	244	·989	1·1
7½	59	300	244	·989	1·1
10	60	300	244	·989	1·1
12½	60	301	244·5	·988	1·2
15	60	301	244	·988	1·2
Means	. . .	. . .	. . .	0·9877	1·23

While these calorimeter tests were made, three samples of boiler water were taken from the gauge cock and three samples of steam condensed in the copper worm. These were carefully analysed by Mr. Crighton, under the direction of Professor Armstrong, F.R.S. The following are the results:—

Boiler Water		Condensed Steam		Moisture in Steam, per cent.
Time	Grams of NaCl in 100 c.c.	Time	Grams of NaCl in 100 c.c.	
11.50 A.M.	1·2678	12.7 P.M.	·0000919	·0073
12.32 P.M.	1·3017	12.28 „	·0002297	·0181
1.14 „	1·2348	1.15 „	·0002756	·0217
Mean . .	1·2681	Mean . . .	. . .	·0157

The percentages of moisture have been calculated from the mean saltness of the boiler water. It will be seen they vary considerably. Further, the moistness from the salt test is only one-hundredth as great as that shown by the wire-drawing calorimeter.

The temperatures for the Barrus calorimeter are plotted in fig. 7, in order to show how remarkably regular and consistent the observations with a wire-drawing calorimeter are.

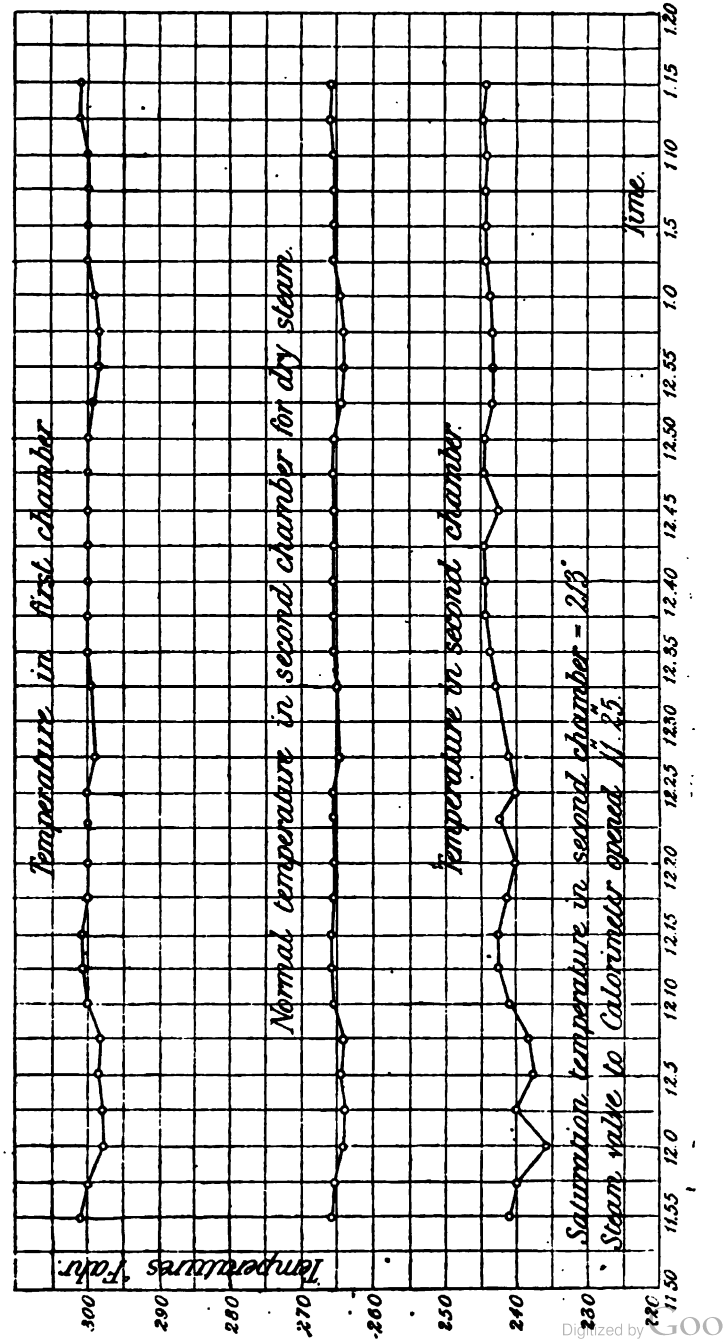
Simultaneous Wire-drawing and Salt Test.—In the following test the Barrus wire-drawing calorimeter was used, the observations being taken by Professor Unwin. Simultaneously Professor Kennedy took samples of the condensed steam and boiler water, and determined the moisture in the steam by the salt test.

Test of Water Tube Boiler, using Wire-drawing Calorimeter, April 11, 1894.—The temperatures of the calorimeter thermometers given are the means of two to five observations at intervals of about one minute, taken after steam had been flowing through calorimeter for about twenty minutes. They were taken as soon as the temperatures had become steady. Barometer 29·936 in.=14·70 lb. per sq. in. Temperature of saturated steam corresponding to pressure in second chamber assumed 214°.

—	Time	Pressure by Gauge on Boiler, lb. per sq. in.	Temperature in First Chamber, t_1	Temperature in Second Chamber, t_2	Dryness Fraction of Steam, x	Moisture in Steam per cent.
April 11 . .	h. m. 10 14 A.M. 10 20 „	160·5	360·25	281·75	·990	1·0
	10 17 „ 10 19 „	158·0	359·75	283·0	·989	1·1
	12 14 P.M. 12 18 „	160·0	361·0	284·0	·990	1·0
	2 20 „ 2 25 „	157·4	360·8	284·3	·990	1·0
	3 16 „ 3 18 „	158·3	360·3	284·5	·991	·9
Means . . .	—	—	—	—	·990	1·0
April 10 .	10 3 A.M. 10 5 „	161·6	357·0	279·3	·988	1·2
	11 12 „ 11 20 „	161·0	357·5	280·6	·989	1·1
	12 17 P.M. 12 21 „	160·8	359·6	282·8	·989	1·1
	2 52 „ 2 55 „	149·0	354·0	281·3	·990	1·0
Means . . .	—	—	—	—	·989	1·1

It is obvious that the salt test shows much less moisture than the calorimeter, the mean moisture by the former being 1 per cent. and by the latter only about one-tenth as much. Naturally the salt test which shows only mechanical priming should give a lower result than the calorimeter. But the salt tests are so irregular that it is impossible not to doubt a little the accuracy of the method.

Fig. 7.—Wire-drawing Calorimeter. Experiment at the Central Technical College, June 5, 1894.



The moisture found by condensing some steam and determining the amount of salt during the same trials was as follows :—

—	Sample	Time	Dryness Fraction	Moisture per cent.
		h. m.		
April 10	1	10 30 A.M.	[·9997]	Less than 0·03
	2	11 38 „	·9965	0·35
	3	12 34 P.M.	[·9997]	Less than 0·03
	4	1 51 „	[·9997]	„
	5	3 40 „	[·9997]	„
Mean . . .	—	—	·9991	0·094
April 11	1	10 35 A.M.	[·9997]	Less than 0·03
	2	11 47 „	·9957	0·43
	3	1 40 P.M.	·9990	0·10
	4	3 42 „	[·9997]	Less than 0·03
Means . . .	—	—	·9985	0·147

Prehistoric and Ancient Remains of Glamorganshire.—Second Report of the Committee, consisting of Dr. C. T. VACHELL (*Chairman*), Lord BUTE, Mr. G. T. CLARK, Mr. R. W. ATKINSON, Mr. FRANKLEN G. EVANS, Mr. JAMES BELL, Mr. T. H. THOMAS, Dr. G. J. GARSON, *and* Mr. E. SEWARD (*Secretary*). (*Drawn up by the Secretary.*)

ALTHOUGH a list of all the known prehistoric and ancient remains of Glamorganshire has been compiled on forms issued by your Committee, the work of specially indicating on maps the ancient remains already registered has not yet been accomplished.

The desirability of increasing opportunities for work among persons in the district has been felt, and the Cardiff Naturalists' Society, with whom the movement originated, have recently formed an archæological section. This course was to some extent due to a visit of the British Archæological Association to Cardiff, during which many objects of prehistoric and archæological interest were investigated and described. The archæological section of the Naturalists' Society consists of about fifty members, and it is intended that one of its objects shall be to assist in registering the position of ancient remains on maps. Your Committee wish to co-operate with the archæological section of the Naturalists' Society, and request the sanction of the Association for carrying this out. Such a connection will tend to widen the interest in the work and to increase the number of those who may be expected to join in it.

It may be stated that the Cardiff Naturalists' Society have already carried out useful archæological work within the county. Of the inspections, reports, and sketches, &c., which have been made, one may be specially mentioned, viz., a paper by Mr. T. H. Thomas on the ancient inscribed crosses of Glamorganshire, beautifully illustrated by photographs, and published in the Society's Transactions for 1893.

During June 1894 an examination of certain mounds on the Ely Racecourse, near Cardiff, was made by the Cardiff Naturalists' Society. These mounds were first discovered by Mr. John Storrie, one of its members. They have proved to be the remains of a considerable Roman villa, and fragments of hypocaust pipes, Samian ware, and light grey prehistoric pottery, together with black pottery and Roman coins, have been found.

Through the Museum Committee of the Cardiff County Council casts in plaster of two of the most remarkable of these crosses have been secured. These casts have lately been placed in the Cardiff Museum as a nucleus of a typical collection of casts of the ancient inscribed stones and crosses of Glamorganshire.

In addition, the whole of the known inscribed crosses, with two or three exceptions, have been photographed by Mr. T. Mansell Franklen, the Clerk of the Peace for Glamorganshire, and these are available for purposes of study in the Reference-room of the Cardiff Central Free Library.

Ethnographical Survey of the United Kingdom.—Second Report of the Committee, consisting of Mr. E. W. BRABROOK (*Chairman*), Mr. FRANCIS GALTON, Dr. J. G. GARSON, Professor A. C. HADDON, Dr. JOSEPH ANDERSON, Mr. J. ROMILLY ALLEN, Dr. J. BEDDOE, Professor D. J. CUNNINGHAM, Professor W. BOYD DAWKINS, Mr. ARTHUR EVANS, Mr. E. SIDNEY HARTLAND, Sir H. HOWORTH, Professor R. MELDOLA, General PITT-RIVERS, Mr. E. G. RAVENSTEIN, *and* Mr. G. W. BLOXAM (*Secretary*). (*Drawn up by the Chairman.*)

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1. As in the previous year, the Committee have had the advantage of the co-operation of several gentlemen not members of the Association, but delegates of various learned bodies who are interested in the Survey. They have to deplore the loss, by death, of one of these gentlemen, Mr. H. S. Milman, director of the Society of Antiquaries, who had been delegated by that Society and had rendered much assistance in the earlier stages of the work. His place has been filled by the election by the same Society of its Vice-President, Mr. Granville Leveson-Gower, of Titsey Place, as a delegate to this Committee. His colleague, Mr. George Payne, and Mr. E. Clodd, Mr. G. L. Gomme, and Mr. J. Jacobs, the representatives of the Folk Lore Society, Sir C. M. Kennedy, K.C.M.G., representing the Royal Statistical Society, Mr. Edward Laws, the Ven. Archdeacon Thomas, Mr. S. W. Williams, and Professor John Rhys, representing the Cambrian Archæological Association, and Dr. C. R. Browne, a representative of the Royal Irish Academy, have continued their valuable services. Some other members of the Committee are delegated by the Anthropological Institute.

2. In their first report the Committee presented a list of 264 villages or places which, in the opinion of competent persons consulted by the Committee, appeared especially to deserve ethnographic study, and they appended to the list observations furnished by their correspondents on the special characteristics of such villages and places, which rendered them typical. This considerable number does not exhaust the supply of names

of places, several more having been received since the first report was prepared.

3. In the first report it was stated that no villages had been suggested in Northumberland. This omission has since been supplied by the kindness of Mr. R. O. Heslop, who has furnished the following list:—

NORTH.—*Tweedmouth*, *Berwick* (Romany influence in folk speech), Ford, *Cornhill*, Lowick, Wooler, *Belford*, Bamburgh, *Embleton*, Longbroughton, *Alnwick*, *Whittingham*, *Warkworth*, *Rothbury*, *Harbottle*, *Elsdon*.

SOUTH.—*Morpeth*, *Whalton*, *Stamfordham*, *Ponteland*.

TYNESIDE (co. of Durham).—Blaydon, Winlaton Swalwill, *Whickham*, Low-Fell, Birtley, Usworth.

NORTHUMBERLAND.—Newburn, *Newcastle* (keelmen's quarter), North Shields.

WEST TYNE.—Wylam, Hedley-on-the-Hill, Slaley, Blanchland, *Corbridge*, *Hexham* (a tinker and Irish quarter), Acomb, Humshagh, *Birtley*, Wark, *Bellingham*, Bardon Mill, Haydon Bridge, Whitfield.

SOUTH-WESTERN (mixture of lead-mining population).—Allendale Town, Allenheads, Slaggyford, Haltwhistle.

Mr. Heslop thinks that capable observers could be obtained at the places printed in italics, and has furnished the following summary of the special features of the district:—

Fishermen (self-contained and intermarried communities).—Berwick, Spital, Holy Island, North Sunderland, Newton, Boulmer, Newbiggin, Cullercoats.

Pilots and *Boatmen*.—North and South Shields.

Pitmen.—Bachworth, Seghill, Acklington.

Keelmen.—Sandgate, (Newcastle), Dunston, Blaydon, Lemington, Felling Shore (co. Durham).

The pitmen and keelmen of the Tyne are chiefly descended from the Border clans.

Shepherds.—Harbottle, Wooler, Head of Reedsdale. (The Cheviot men, of the wide district embracing the Cheviot range on the Northumberland side, would have to be observed from these points.)

4. Mr. E. W. Cox, of Bebington, has furnished the following list of places in the neighbourhood of that part of Cheshire and Lancashire:—

Norton, near Runcorn.
Farnworth, near Warrington.
Frodsham.
Kelsby.
Delamere Forest.
Hale.
Speke and Oglct.
Woolton.
Wavertree.
West Derby.
Walton.
Crosby.
Fazakerley.
Formby.
Ormskirk.
Burscough.
Altcar.
Sefton.
Maghull.
Rufford.
North Meols, Lancashire.
Mealse, in the district of Meols, in Cheshire.
Grange.

HEIGHT		CRANIUM		FACE				
Standing	Sitting	Length	Breadth	Length	Upper Face Length	Breadth	Interocular Breadth	Bigonial Breadth

NOSE		Height of Head	Height of Cranium
Length	Breadth		

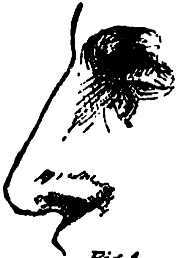

Fig 1.

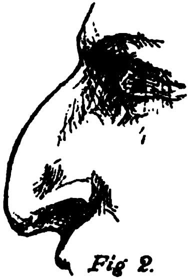

Fig 2.

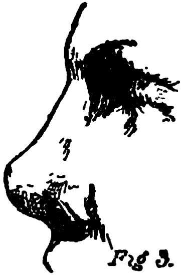

Fig 3.

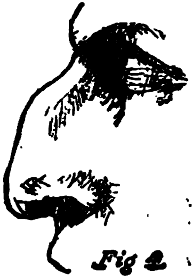

Fig 4.

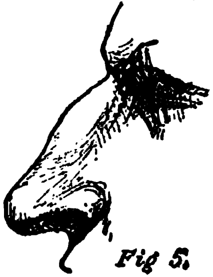

Fig 5.

APPENDIX II.

Directions for Measurement.

Instrument required for these measurements:—The 'Traveller's Anthropometer,' manufactured by Aston & Mander, 25 Old Compton Street, London, W.C.; price 3*l.* 3*s.* complete; without 2-metre steel measuring tape and box footpiece, 2*l.* 10*s.* With this instrument all the measurements can be taken. In a permanent laboratory it will be found convenient to have a fixed graduated standard for measuring the height, or a scale affixed to a wall. For field work a tape measure may be temporarily suspended to a rigid vertical support, with the zero just touching the ground or floor. A 2-metre tape, a pair of folding callipers, a folding square, all of which are graduated in millimetres, and a small set-square can be obtained from Aston & Mander for 1*l.* 6*s.*; with this small equipment all the necessary measurements can be taken.

Height Standing.—The subject should stand perfectly upright, with his back to the standard or fixed tape, and his eyes directed horizontally forwards. Care should be taken that the standard or support for the tape is vertical. The stature may be measured by placing the person with his back against a wall to which a metre scale has been affixed. The height is determined by placing a carpenter's square or a large set-square against the support in such a manner that the lower edge is at right angles to the scale; the square should be placed well above the head, and then brought down till its lower edge feels the resistance of the top of the head. The observer should be careful that the height is taken in the middle line of the head. If the subject should object to take off his boots, measure the thickness of the boot-heel, and deduct it from stature indicated in boots.

Height Sitting.—For this the subject should be seated on a low stool or bench, having behind it a graduated rod or tape with its zero level with the seat; he should sit perfectly erect, with his back well in against the scale. Then proceed as in measuring the height standing. The square should be employed here also if the tape against a wall is used.

Length of Cranium.—Measured with callipers from the most prominent part of the projection between the eyebrows (glabella) to the most distant point at the back of the head in the *middle line.* Care should be taken to keep the end of the callipers steady on the glabella by holding it there with the fingers, while the other extremity is searching for the maximum projection of the head behind.

Breadth of Cranium.—The maximum breadth of head, which is usually about the level of the *top* of the ears, is measured at right angles to the length. Care must be taken to hold the instrument so that both its points are exactly on the same horizontal level.

Face Length.—This is measured from the slight furrow which marks the root of the nose, and which is about the level of a line drawn from the centre of the pupil of one eye to that of the other, to the under part of the chin. Should there be two furrows, as is often the case, measure from between them.

Upper Face Length.—From root of nose to the interval between the two central front teeth at their roots.

Face Breadth.—Maximum breadth of face between the bony projections in front of the ears.

Inter-ocular Breadth.—Width between the internal angles of the eyes. While this is being measured the subject should shut his eyes.

Bigonial Breadth.—Breadth of face at the outer surface of the angles of the *lower* jaw below the ears.

Nose Length.—From the furrow at root of nose to the angle between the nose and the upper lip in the middle line.

Breadth of Nose.—Measured horizontally across the nostrils at the widest part, but without compressing the nostrils.

Height of Head.—The head should be so held that the eyes look straight forward to a point at the same level as themselves—i.e. the plane of vision should be exactly horizontal. The rod of the Anthropometer should be held vertically in front of the face of the subject, and the upper straight arm should be extended as far as possible and placed along the middle line of the head; the shorter lower arm should be pushed up to the lower surface of the chin. When measured with the square the depending bar must be held vertically in front of the face (with the assistance of the spirit-level or plumb-line), and the small set-square passed up this arm from below in such a manner that its horizontal upper edge will come into contact with the lower contour of the chin. The distance between the lower edge of the horizontal bar of the square and the upper edge of the set-square can be read off, and this will be the maximum height of the head.

Height of Cranium.—The head being held in precisely the same manner as in measuring the height of the head, the instrument is rotated to the left side of the head, its upper bar still resting on the crown, and the recording arm (or the set-square) is pointed to the centre of the line of attachment of the small projecting cartilage in front of the ear-hole.

NOTE.—It is essential that these rules should be strictly followed in order to secure accuracy. All measurements must be made in millimetres. If possible, the subject's weight should be obtained, and recorded in the place set apart for remarks. The observer is recommended to procure 'Notes and Queries on Anthropology,' 2nd edition, from the Anthropological Institute, 3 Hanover Square, London, W.; net price, 3*s.* 6*d.*

APPENDIX III.

The Ethnographical Survey of Ireland.—Report of the Committee, consisting of Dr. C. R. BROWNE, Professor D. J. CUNNINGHAM, Dr. S. HAUGHTON, Professor E. PERCEVAL WRIGHT, *and* Professor A. C. HADDON (*Secretary*). (*Drawn up by the Secretary.*)

The following is a brief statement of the work done by the Committee of the Ethnographical Survey of Ireland.

DUBLIN.

A note[1] on the steps then taken and the chief objects in view was read before the Anthropological Institute in August 1891. In December of the same year Dr. Browne made a communication[2] to the Royal Irish Academy on some instruments.

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[1] Cunningham, D. J., and Haddon, A. C., The 'Anthropometric Laboratory of Ireland,' *Journ. Anthrop. Inst.*, vol. xxi. 1891, pp. 35–38.

[2] Browne, C. R., 'Some New Anthropometrical Instruments,' *Proc. Roy. Irish Acad.* [3], vol. ii. 1892, pp. 397–399, 2 figs.

Measurements and observations have since then been continuously made in the Anthropometric Laboratory in Trinity College, Dublin, and up to the present time nearly 500 persons have been measured. The tabulation of the results has been commenced.

The first ethnographical field excursion was to the Aran Islands in Galway Bay. Instead of attention being confined to anthropometric data it was deemed advisable to make a sociological study of the people as well. The table of contents of the report [5] as read before the Royal Irish Academy on December 12, 1892, is as follows:—'I. INTRODUCTION; II. PHYSIOGRAPHY; III. ANTHROPOGRAPHY. 1. *Methods*: (A) Hair and Eye Colour, (B) Head, Face, and Body Measurements, (C) Instruments used, (D) General Remarks on Methods employed, (E) Photography. 2. (A) *Physical Characters*, (B) Statistics of Hair and Eye Colour, (C) Detailed List of Measurements, (D) Analysis of the Statistical Tables. 3. *Vital Statistics* (General and Economic): (A) Population, (B) Acreage and Rental, (C) Language and "Illiterancy," (D) Health. 4. *Psychology*. 5. *Language*, Folk-names. IV. SOCIOLOGY. 1. *Occupations*; 2. *Family-life and Customs*; 3. *Clothing*; 4. *Dwellings*; 5. *Transport*. V. FOLK-LORE; VI. ARCHÆOLOGY. 1. *Survivals*; 2. *Christian Antiquities*; 3. *Pagan Antiquities*. VII. HISTORY; VIII. ETHNOLOGY; IX. BIBLIOGRAPHY.'

The second expedition was to Inishbofin and Inishshark, islands off the North Galway coast. The report,[9] which was on the same lines as the previous one, was read before the Academy on November 30, 1894.

The craniology of the Irish has not been neglected by the Committee, and accounts have been published of crania from the Aran Islands,[4] Inishbofin [8], [9], and co. Tipperary.[3] Dr. W. Frazer also describes two Irish crania in 'Proc. Roy. Irish Acad.' [3], vol. ii. 1893, pp. 643–647.

For folk-lore papers [5], [6], [7], and [9] may be consulted.

This summer Dr. Browne made a third expedition to the west coast of Ireland, and has brought back a large series of measurements and observations from the district of Erris, in co. Mayo, which will be duly published by the Royal Irish Academy.

BELFAST.

An ethnographical committee has been established in Belfast. An account of its formation will be found in the 'Annual Report and Proceedings of the Belfast Naturalists' Field Club,' iii. 1892–93, p. 542, and

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[3] Browne, C. R., 'On some Crania from Tipperary,' *Proc. Roy. Irish Acad.*, 1893, pp. 649–654.

[4] Haddon, A. C., 'Studies in Irish Craniology: The Aran Islands, Co. Galway, *Ibid.*. pp. 759–767.

[5] Haddon, A. C., and Browne, C. R., 'The Ethnology of the Aran Islands, Co. Galway,' *Ibid.*, pp. 768–830, 1 fig. pls. xxii.–xxiv.

[6] Haddon, A. C., 'A Batch of Irish Folk-lore' (with collections by Miss Emily Fitzgerald, Miss Sinclair, Mr. D. H. Lane, Dr. C. R. Browne, Miss G. C. Campbell, Miss A. Watson, and others), *Folk-lore*, vol. iv. 1893, pp. 349–364.

[7] Haddon, A. C., 'The Aran Islands, Co. Galway: A Study in Irish Ethnography,' *Irish Naturalist*, vol. ii. 1893, pp. 303–308, pl. viii. (abstract of No. 5).

[8] Haddon, A. C., 'Studies in Irish Craniology: II. Inishbofin, Co. Galway,' *Proc. Roy. Irish Acad.* [3], vol. iii. 1894, pp. 311–316.

[9] Browne, C. R., 'The Ethnography of Inishbofin and Inishshark, Co. Galway,' *Ibid.*, pp. 317–370, pls. viii., ix.

iv. 1893–94, p. 52. The half-dozen papers, [1–6], that have been published by the Belfast Committee are on purely folk-lore subjects. This energetic club also studies local archæology, which is also, within limits, a branch of ethnography. Since the Committee has been formed the following papers have been published :—Gray, W., paper on 'Worked Flints : Ancient and Modern' (vol. iii. pp. 548–569, 3 figs., pls. i.–viii.) ; Dickson, J. M., 'Relative Antiquity of Rath, Cromleac, and Burial Tumulus, as evidenced by some Ancient Remains near Dromore, Co. Down' (vol. iv. pp. 55–70, 1 fig.) ; Bigger, F. J., 'Prehistoric and Historic Forts and Raths in the City and Vicinity of Belfast' (iv. pp. 71–81, 4 plans). Mr. R. Welch, a member of the Committee, is making a most valuable series of photographs illustrative of the ethnography of Ireland, especially of Ulster.

The Lake Village at Glastonbury.—Report of the Committee consisting of Dr. R. MUNRO (*Chairman*), Mr. A. BULLEID (*Secretary*), Professor W. BOYD DAWKINS, General PITT-RIVERS, *and* Sir JOHN EVANS. (*Drawn up by the Secretary.*)

THE work at the British lake village near Glastonbury has been much retarded by the flood-water that accumulated during the winter, and by the heavy rains during the spring. Digging had to be abandoned last autumn a fortnight after the Association meeting at Nottingham, and it was not until the early part of May this year that the water had fallen low enough to allow a recommencement of the investigations ; even up to the date of writing, July 10, it is still necessary to keep the pumps in daily use. During the seasons of 1892 and 1893 the time was chiefly taken up with the examination of fifteen dwelling mounds, and of the causeway and other stone and timber structures in the peat outside the village margin. This year, so far, has been occupied with tracing the village border to the extent of 550 feet, or about one-third of its total circumference ; and the investigations have not only brought to light much valuable information relating to the size and shape of the village, but have established the following facts :—

(*a*) That the village was originally surrounded by the water of a shallow mere.

(*b*) That five feet of peat accumulated during its occupation.

(*c*) That a strong palisading of posts and piles protected the village.

(*d*) That the groundwork of the village, so far at least as its margin is concerned, is artificial for the depth of five feet.

The palisading at the edge of the village is formed of piles three to nine inches in diameter, and from five to eleven feet in length, kept together by more or less coarse hurdle-work. Although in many places the piles are much displaced and decayed, yet they form a fairly perfect and continuous though irregular line—at some parts they are placed so

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[1] Bigger, F. J., 'Local Folk-lore,' Belfast Nat. Field Club, *Ann. Rep. and Proc.* [2], vol. iii. 1892–93, pp. 545–548.

[2] Mollan, Lily S., 'Pishogues from Tipperary,' *Ibid.*, pp. 571–573.

[3] Patterson, W. H., 'Irish Fairies,' *Ibid.*, pp. 573–583.

[4] Blair (Mrs.), 'Items of Folk-lore, principally from Co. Down,' *Ibid.*, pp. 583–586.

[5] Patterson, Clara M., 'A Few Children's Games,' *Ibid.*, vol. iv. 1892–94, pp. 48–52.

[6] Gray, W., 'Our Holy Wells : A Folk-lore Chapter,' *Ibid.*, pp. 86–95.

closely together that from fifty to seventy have been counted in the space of ten feet. The majority slope outwards, having the appearance of *chevaux de frise*, at angles varying with the state of preservation of the border; but a large proportion of them were undoubtedly driven in vertically, and have been either broken off or gradually forced out into their present position. Some piles barely reach the true peat, whilst others pierce it for several feet; occasionally a few vertical piles are still seen among the slanting: these probably show repairs to the border.

The border of the village has a very irregular outline, the piles being arranged in varying curves: this unevenness has been proved in some places to be due to extension of the village. The surface of the border immediately inside the piles is formed of trunks of trees and large pieces of timber placed side by side parallel to the margin, and reaching eight to twelve feet inwards; underneath these more timber is found, alternating with layers of clay and brushwood, with which are intermingled patches of stone, peat, rush, and bracken to the depth of five feet.

Numerous and important objects have been unearthed this season from the peat outside the village at all depths down to seven feet three inches, and as far as eighty feet from the village border. Pottery—hand and wheel made—clay pellets (so-called sling-stones), baked and unbaked, and bones of animals are still met with at all points in great quantities. Recently a decorated wheel-made bowl of black ware has been found in perfect preservation and highly finished, four inches high, and five inches across the rim, besides numerous other pieces of pottery elaborately marked with designs of circles, curved and flowing lines, and triangles. Many of these fragments are doubtless capable of reconstruction.

Flint.—Besides several scrapers, one good arrow-head.

Bronze.—The find of greatest importance in this metal has been a well-preserved bowl measuring 4½ inches across the rim. It is made of two pieces riveted together: the outside decoration consists of the row of rivet-heads or bosses almost an inch below the rim, and two fine lines of punched work near the edge; the under surface is semicircular, and a hole in it had been evidently made good by riveting on a small piece. Amongst the other objects of bronze are two more spiral finger-rings and a pen-annular ring brooch.

Iron.—Of this metal there is a reaping hook, together with its wooden handle, sixteen inches in length, and a primitive sickle with riveted wood handle complete, in length ten inches.

Lead.—A spindle whorl decorated with three parallel lines, and a flattened disc or weight of about one and a quarter inch in diameter.

Bones.—More human remains have been met with this year than previously, including a complete skull showing several sword or axe-marks: no other bones belonging to the body were discovered near it.

Professor Boyd Dawkins has examined the sample of animal bones forwarded to him, and among them he has found the following mammals and birds represented:—

Domestic Mammals	*Domestic Birds*
Bos longifrons	Gallus domesticus
Capra hircus	
Ovis aries	
Sus scrofa	
Equus caballus	
Canis familiaris	

Wild Mammals

Felis catus ferus
Lutra vulgaris
? Canis lupus
Sus scrofa ferus
Castor fiber
Cervus elaphus
Cervus capreolus
Arvicola amphibia

Wild Birds

Crane abundant
Swan abundant
Heron
Diver, species ?
Mallard
Grebe

Many very interesting objects have been found this year made of cut wood, amongst them being seventeen pieces of a mortised framework, probably part of a second loom, another having been found last summer.

Portions of a small stave-made bucket with decorated side. The greater part of a solid cut tub in fragments, six inches high, and about twelve inches in diameter, the outside decoration being of a very bold and beautiful description.

Part of the axle of a wheel, with bases of two spokes *in situ*. The length of the axle is fourteen inches, its diameter six inches, and the length of a spoke being twelve inches. The whole is of light construction and of perfect workmanship, and was probably a potter's wheel.

A large font-shaped block of timber, three feet high and two feet in diameter. The top is flat, showing complete impressions of the sharp edge of the axe with which it was cut.

Unbaked clay pellets, or so-called sling-stones, have been found in hundreds, and among the other things dug out of the peat are spindle whorls, quern stones, wattle, and crevice-marked clay, and portions of loom weights. The bones of animals have been met with in such quantities in some places that a wheel-barrow full has been obtained from a square yard of peat.

The botanical specimens have been submitted to Mr. J. G. Baker, F.R.S., of Kew, who has kindly given the following report, and further specimens are to be forwarded to him.

'Report on the peat from the British village at Glastonbury :—

'*Leaves.*—It contained abundant leaves of *Salix cinerea*, a species everywhere abundant in Britain at the present time, not restricted to damp places. On some of the leaves were found *Rhytisma Salicinum*, a minute fungus. There were a few leaves of *Myrica Gale.*

'*Twigs.*—Probably these belong to *Salix cinerea.*

'*Seeds.*—The abundant seeds represent three genera—Ranunculus, Potamogeton, and Carex. All these are large genera, and it is impossible to say which species they represent. Potamogeton indicates a lake or pool.

'Altogether the peat contains nothing whatever that might not be found living in the surrounding district at the present time.'

Very careful and accurate notes are taken of everything that is found, and all piles, posts, large pieces of timber, and stone are marked on the plans ; the depth at which important objects are found is also noted, and photographs are taken and drawings made.

There still remain two-thirds of the village border to be traced, and nearly fifty dwelling mounds and about five-sixths of the entire village area to be examined.

All the objects that it has been possible to move to the Glastonbury Museum have already been placed and arranged there in the cases; but the finest specimens of cut woodwork are of too perishable a nature to be kept in the museum, and are at present kept in zinc troughs at Mr. Bulleid's house.

Physical and Mental Deviations from the Normal among Children in Public Elementary and other Schools.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Dr. FRANCIS WARNER (*Secretary*), Mr. E. W. BRABROOK, Dr. GARSON, Mr. G. W. BLOXAM, *and* Dr. WILBERFORCE SMITH. (*Report drawn up by the Secretary.*)

APPENDIX PAGE
I. *Certificate as to a Child requiring Special Educational Training* . . 437
II. *Statistical Report concerning* 50,000 *Children* 437
III. *Distribution of the Cases seen as to Standards* 438

THE Committee, acting in conjunction with a Committee appointed for the same purpose by the International Congress of Hygiene and Demography, are now able to report on 50,000 children seen individually in sixty-three schools by Dr. Francis Warner, 1892–94.

The methods of examination employed, and the points observed, were described fully in our last report. A complete actuarial investigation of the 8,941 children deviating from the normal in some respect, of whom notes were taken, is in hand. Some portions of the statistical results are appended. The general conclusions arrived at, and recommendations founded on the observations, are now given.

It is quite possible to report on any group of children, or group of schools, as to the physical and mental conditions most prevalent among them, and to compare these with an established average.

Groups of children, arranged according to their physical condition, may be traced through the educational standards of the school, thus showing that unconsciously those of defective body and brain condition remain mostly in the lower standards, and are frequently over age for the standard in which they are found.

The ages at which the children present certain physical and nerve-irregularities can be traced, thus affording a basis for the determination of the age-prevalence of defective conditions, and the most frequent ages at which they appear and disappear.

The general results of detailed study of the conditions of school children show that—

There is a large group of children who appear to need special care and training, including the crippled, maimed, deformed, and paralysed; children mentally deficient or presenting some deficiency; and epileptics:—Boys, 157; Girls, 147.

To these may be added children constitutionally weak and dull, making altogether about sixteen per 1,000 of the child population. As to methods of reporting and certifying these cases, see last paragraph of this report.

Defects in development indicate inherited and congenital tendency to delicacy, both of body and in brain action; they are extremely frequent in all classes of society, not least so among the upper social grades. It appears probable that, to a great extent, such defects may be rendered less numerous among the population by hygienic care with regard to buildings, light and air, &c.

As to children presenting irregularities of the nerve-system, their careful training may do much to prevent them from growing up permanently nervous or mentally dull. Many children unconsciously imitate habits of listlessness, inattention, carelessness, and even the appearances of fatigue and hysteria from one another, or from their teachers.

The knowledge gained renders it possible to indicate the kind of training adapted to any case described. This particularly applies to the nerve-signs, or irregularities in nerve-action recorded. After pointing out to the teacher the irregularities present in the child, so that their increase or decrease can be watched during class work, indications may be given as to the best modes of removing these special nervous and mental defects. That such explanations may be understood by the teachers it is very desirable that they should receive some special instruction. Economy in the labour of teachers might thus be effected, and better educational results obtained.

School organisation by the teachers is mainly founded upon their experience of the child's mental ability and work in school. This takes time, and frequently a new pupil is not placed in a suitable standard till some weeks of experience show the child's mental capacity. A knowledge of the points observed in this inquiry might facilitate the responsible work of classification for educational purposes.

Two standards frequently, though not always, met with in a school call for special remark. In Standard 0, or Primers, the children are collected who, being over age for the infant school, are still too backward for Standard I. In Standard Ex. VII. we find the children who have passed through the ordinary classes of the school. The experience of hospital physicians and many philanthropic societies shows that neglect of feeble-minded children of all grades leads to much social evil. The blind and the deaf are happily now cared for under the provisions of the Elementary Education Act, 1893, and teachers are specially trained for this work; but the children of the various grades of feebleness short of imbecility, children who present a deficiency, are in many schools unwelcome, and no encouragement is given to school authorities to collect and care for them; they are an incumbrance if not properly provided for, and untrained they tend to social failure, pauperism, and criminality. Mere accumulations of dull children in a certain class, whether a class of Primers, or in a lower section of Standard III. for older children, may make the other class-rooms brighter, but, when children below average power are accumulated, there arises a greater responsibility for their individual care, which must be met by the provision of a sufficient staff of specially trained teachers. Scientific advice as to the management of deficient children is useful, but teachers must carry out the details of special training. Nurses for the sick are now highly trained and well paid; they take an intelligent interest in the patients; the more difficult the case, and the more attention it requires, the greater are their interest and desire for success. Training of teachers for the care of the more difficult children, and honour for the hard work of improving feeble children, may cultivate a higher professional interest among a body of skilled teachers trained to the charge of feeble children. Considerable success has been achieved in training the blind and the deaf, and a large proportion of the feeble children are improvable.

Secondary education tends to accentuate the difficulties arising from the classification of children solely according to mental status. In elementary schools of higher grade, a boy entering Standard I. in the upper school is unacceptable unless he can work well; after a certain age, the dull boy cannot conveniently be kept in the infant school; he is too big. He must then either be kept among the infants, for whom he is not good company, or go among classmates with whom he cannot profitably work. To meet such cases it often happens that there is a class of Primers, but without any special arrangements for individual culture. In such schools the brighter children are well educated; at fourteen they get the prizes of the school and enter social life at an advantage; the dull children have not only been left comparatively uncultured, but by raising a class distinctly superior to themselves, they find the struggle for existence becoming intensified.

In all public expenditure, sums of money spent in secondary education should be accompanied by a proportional expenditure for the benefit of the dull and weak children. This is equivalent to the enactment which requires that schemes for the sanitary improvement of a neighbourhood, while providing good new dwellings, should also make provision for the poorer population displaced thereby. The child of good inheritance in brain power receives free education, and in consequence makes the dull child's life more difficult. The public interest requires that each child shall be trained to get a living.

Recommendations :—

That a scientific statement of all observable conditions of child-life—including elementary anthropometric examination—should be prepared by observation of at least 100,000 children.

That School Boards, in taking their triennial census of children in their district, should register any mentally defective children, or children otherwise afflicted.

That teachers should be specially trained to undertake the educational care of weak and mentally feeble children.

That lectures should be provided on the observation, study, and classification of children as to conditions bearing on mental life and education. This might consist of an elementary course and of University teaching.

That the Act to make better Provision for the Elementary Education of Blind and Deaf Children in England and Wales [56 and 57 Vict.], chap. 42, should be extended to include children with mental and bodily defects incapacitating them from ordinary school instruction.

That in the appropriation of funds for secondary education a proportional sum should be devoted to the special training of the dull and feeble.

That the Government be recommended to consult a scientific expert to assist the Education Department, the Local Government Board, and the Home Office in carrying out the above recommendations, and to report upon the whole subject generally as to the care of children whose education is supervised by the Government.

A form suggested for certification of a feeble-brained or defective child as requiring exceptional training is appended. Another certificate by a school teacher might be required if the child is attending school.

The Committee desire to be reappointed as before, and ask a further grant in aid of the work.

APPENDIX I.

Certificate as to a Child requiring Special Educational Training.
To be filled in by a Medical Officer.

Name of child______________________________
Age______________________________
Address______________________________
Physical health and condition______________________________
Developmental defects______________________________
Nervous defects______________________________
Defects in mental power______________________________
Facts communicated by others______________________________
(stating from whom)
Opinion and recommendation as to the case______________________________
Date ______________(Signed) Medical Officer______________

APPENDIX II.

Statistical Report concerning 50,000 *Children examined* 1892–94.

(Boys 26,287. Girls 23,713.)

	Boys	Girls
Total number of children reported by teachers as dull at lessons	2,074	1,634
Total number of children reported as pale, thin, or delicate	749	770
Total number of children with nerve-signs	2,853	2.015
Total number of children presenting a defect in development of body	2,308	1,618
Children with low constitutional power, delicate, and dull	80	79
Children crippled, maimed, paralysed; those of defective mental development, and pupils with history of fits during school life	157	147
Children using glasses and with eye defects	774	715
Children with defects of cranium	706	622
Children with defects of palate	496	324
Children with defects of external ears	664	110
Children with defect in development of body only	802	445
Children with defect in development of body and nerve-signs only	415	207
Children with defect in development of body and low nutrition only	134	162
Children with defect in development of body and dull only	394	314
Children with defect in development of body with nerve-signs and low nutrition only	69	77
With defect in development, nerve-signs, and dull only	323	224
With defect in development, low nutrition, and dull only	91	110
With defect in development, low nutrition, nerve-signs, and dull	80	79
Total number of children with some defect in development in body	2,308	1,618
Children with abnormal nerve-signs only	1,059	762
Children with abnormal nerve-signs and low nutrition only	115	109
Children with abnormal nerve-signs and dull only	703	487
Children with abnormal nerve-signs, low nutrition, and dull only	89	70
Children pale, thin, or delicate (low nutrition) only	108	110
Children on low nutrition and dull only	63	53
Children reported as dull only without other defect	331	297
Total number of cases reported in this inquiry with a defect	5,112	3,829

APPENDIX III.

For 50,000 *Children as seen in Sixty-three Schools. Distribution of the Cases seen as to Standards. Distribution of Cases noted as presenting some Defect according to Standards and Ages.*

Ordinary Age of Standard	3 to 6 years		6	7	8	9	10	11	12	13	—	—
Standard	Infants	0.	I.	II.	III.	IV.	V.	VI.	VII.	Ex. VII.	Not in Standards	Totals
	BOYS GIRLS	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	Boys	B. G.
No. of children seen	7055	354	4231	3710	3541	2760	2195	1471	598	144	228	26287
	6274	323	4191	3465	3434	2534	1797	1078	486	131		23713
No. of children noted	1072	130	1016	817	727	542	391	255	82	23	57	5112
	815	135	743	632	569	392	266	178	81	18		3829
Age last Birthday	3 and under	4	5	6	7	8	9–10	11–12	13	14 & over	—	Totals
	BOYS GIRLS	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.	B. G.		B. G.
Children noted distributed as to age last birthday	57	156	320	492	614	683	1310	1146	242	92	—	5112
	59	113	281	339	466	493	995	824	190	69		3829

Anthropometric Work in Schools.—Report of a Committee, consisting of Professor JOHN CLELAND (*Chairman*), Mr. G. W. BLOXAM, Mr. E. W. BRABROOK, Dr. J. G. GARSON, Professor A. MACALISTER, *and* Professor B. WINDLE (*Secretary*). (*Drawn up by the Secretary.*)

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IN order to ascertain in what schools anthropometric work was being carried on, and in what manner, also what prospect there was of further development in this direction, a circular was prepared, a copy of which is subjoined to this report (Appendix I.).

This circular, together with a letter asking that it might be filled up and returned, and a stamped and directed envelope, was sent to 624 schools—495 for boys and 129 for girls. The former included all those given in 'Whitaker's Almanack.' The latter were the schools whose mistresses belong to the Association of Head Mistresses of Endowed and Proprietary Schools. A large number of these institutions did not reply, but 398 returns were obtained—viz. 309 boys' and 89 girls' schools.

The results obtained from these returns are as follows:—

1. Measurements are taken in 58 schools, of which 11 are for girls and 47 for boys.

2. By whom taken:—

a. Master or mistress	20
b. Medical attendant	3
c. Drill or gymnastic instructor	31
d. Other official	3
e. Not stated	1

3. How often taken:—

At entrance	2 cases
Annually	15 ,,
Twice a year	6 ,,
Three times a year	20 ,,
Four times a year	1 case
Six times a year	11 cases
Not stated	3 ,,

4. Observations taken:—

	Girls' Schools.	Boys' Schools.
Height	9	42
Weight	7	33
Chest-girth	5	36
Length of arm	1	4
Girth of arm	1	14
Length of forearm	1	3
Girth of forearm	1	19
Size of head	3	4
Eyesight	6	8
Hearing	3	2

	Girls' Schools.	Boys' Schools.
Colour-blindness	2	1
Strength of grasp	2	1
Lifting power	1	2

5. How taken:—

Height in boots	4
„ gymnastic shoes	9
„ socks	36
„ bare feet	2
Weight in ordinary clothes	17
„ gymnastic clothes	21
„ naked	2
Chest-girth in ordinary clothes	6
„ gymnastic clothes	16
„ naked	19

6. Reports are sent to parents either regularly, occasionally, or at leaving from 15 schools.

7. Calculations are published in two instances.

Eighty-six schools responded in the affirmative to the eighth question, and a few others provisionally upon the expense not being too heavy.

In response to the requests made by the masters and mistresses of these schools, and by others who did not express any intention of carrying out the work, but were desirous of ascertaining what might be done in this direction, a circular of suggestions for carrying out anthropometric observations was prepared, and has been sent to 162 schools (this circular forms Appendix II.). In preparing this circular the Committee had the valuable assistance of Mr. Priestley Smith in the portion relating to vision, and Mr. Frank Marsh in that respecting hearing; and they desire to record their indebtedness to these gentlemen.

APPENDIX I.

Circular sent to Schools.

A.—Are systematic measurements carried out upon the
in School?

If so—

1. By whom?
2. How often?
3. What are they?

Height
Weight
Chest-girth
Length of arm
Girth of arm
Length of forearm
Girth of forearm

Size of head
Eyesight
Hearing
Colour-blindness
Strength of grasp
Lifting power

(Please erase those not in use.)

4. How are they taken ?

(*a*) Height in boots
„ gymnastic shoes
„ socks
„ bare feet

(*b*) Weight in ordinary clothes
„ gymnastic clothes
„ naked

(*c*) Chest-girth in ordinary clothes
„ gymnastic clothes
„ naked

(In each case, please erase the methods not adopted.)

5. Are reports sent to parents ?

6. Are any calculations published ?

7. If so, can you favour me with a recent copy ?

8. In the event of other schools consenting to do so, would you be prepared to give your adhesion to a scheme by which the same measurements should be carried out in an identical manner throughout the country, seeing that such a course would greatly add to the value of the results obtained ?

B.—In the event of no measurements being now carried out, will you be good enough to inform me whether there is any prospect of your undertaking such work, and, if so, whether I can be of any assistance to you in indicating the best methods and appliances ?

APPENDIX II.

Suggestions for Anthropometric Observations in Schools.

Group A.—*Essential Observations.*

I. Height.—To be taken in socks or stockings. The subject should stand perfectly upright, the head held so that the line of vision is horizontal—that is, the eyes directed horizontally forwards to a point on the same level as their pupils. Any good sliding rod may be used, such as the Laboratory Stadiometer, supplied by Messrs. Aston & Mander, 25 Old Compton Street, Soho, London. (Price 2*l.* 2*s.*)

II. Weight.—To be taken in gymnastic clothes where possible ; a spring balance should not be used. A good machine is supplied by Messrs. W. & T. Avery, of Birmingham (No. 139, special cash price, without chair or rod, 3*l.* 15*s.*). The measuring-rod attached to it should not be purchased.

III. Chest-girth (for boys only).—To be taken over the naked chest with a Chesterman's steel tape (price 5*s.* 6*d.*, Bailey & Co., Bennett's Hill, Birmingham) in the following manner:—(1) The boy stands upright, with the arms stretched from the sides, the measurer standing behind him. (2) The tape is placed over the chest immediately above the nipples, and with the lower edge touching them; it is then brought horizontally round the chest walls, over the blade-bones to the back. The zero of the tape should rest on the spine. (3) The boy drops his arms. (4) Takes a deep breath. (5) Counts slowly from one to ten. (6) At the word 'ten' the measurer draws the tape tight and records the measurement. When this is done, care should be taken to see that the tape is exactly horizontal both in front and behind.

The above measurements should be taken twice (or, if desired, thrice) annually.

IV. Tests of Vision.—These tests will serve to detect the presence of certain common defects of vision. Such defects are often overlooked or disregarded, to the permanent detriment of the pupil. The tests will not reveal the nature or cause of a defect. This can only be determined by an expert.

(*a*) Acuteness of Vision.—(1) Hang on the wall, in a good light, a set of Snellen's Test Letters; these are in general use, and afford records which can be universally compared. *No others should be substituted for them.* (2) Draw a line on the floor at a distance of exactly six metres from the letters, and let each pupil in turn toe this line and try to read the letters, line after line, beginning at the top; in all cases without spectacles or eye-glasses. Each eye is to be tested separately, the other eye being covered, but not pressed upon, by a large card held in the pupil's hand. (3) Record the vision of each eye separately in the form of a fraction; for instance, thus :—

$$\text{R.}\quad V = \tfrac{6}{6}$$
$$\text{L.}\quad V = \tfrac{6}{18}$$

The numerator is in all cases 6—i.e. the distance of the letters in metres; the denominator is the number which stands over the lowest line of letters which can be read. When the vision is less than $\frac{6}{60}$ it should be recorded by the appropriate sign—viz. $V < \frac{6}{60}$. (4) Take care that the pupils have no opportunity of learning the letters by rote.

Note.—When the vision of either eye is found to be represented by a fraction having a denominator of more than 18, it will generally be desirable to report the fact to the parent or guardian, in order that proper advice may be obtained, such report being omitted if this has already been done.

(*b*) Colour Vision.—(1) Use Holmgren's Series of Coloured Wools. (2) Place them in a heap on a white cloth, in a good light. (3) Lay, apart from the heap, the test skein—a pale, pure green. (4) Explain to the pupil that he is to select from the heap and place beside the test skein all those which appear to him to be of the same kind of colour. Do not require him to name them or match them exactly, but to select those which are most nearly like the test-skein in colour. (5) Mix the wools again for each pupil, but always use the pale pure green as the test.

A certain number of the pupils—boys, very rarely girls—will match the test-skein falsely with buffs, pinks, and other colours which have no green tint, or will hesitate much before rejecting such. These pupils are more or less colour-blind, and are thereby permanently unfitted for vocations on land or sea which require good colour vision. Record the defect.

Note.—Ascertain by this same test that the person who conducts the colour-testing is not himself colour-blind. Such cases have been known.

The *Acuteness of Vision* of each pupil should be tested once a year, since certain defects of eye-sight commonly begin during school life.

The test for *Colour Vision* need not be repeated, since colour-blindness, except that which occurs with disease of the eye, is congenital, not acquired.

The test-letters (price 4*s*. 6*d*. framed) and coloured wools (price 4*s*. 6*d*.) may be obtained from Messrs. Bailey & Co., Bennett's Hill, Birmingham, or other makers of optical instruments.

V. HEARING (*Voice Test*).—(1) Instruct the pupil to close the eyes and to repeat any words spoken by the observer. (2) The observer should stand at the opposite side of the room and say words for the pupil to repeat, pitching his voice in an ordinary conversational tone. (3) The observer should gradually approach the pupil until he is distinctly heard. (4) The distance should be compared with that at which words, uttered in the same tone, are heard by a person of known good hearing. (5) In order to test the hearing power of each ear separately, the pupil should stop one with his finger whilst the other is being examined.

(*Watch Test*).—(1) The greatest distance at which the tick of the watch to be used can be heard must be ascertained by testing with it a person of known good hearing. (The hearing distance of an English lever watch is about 60 inches.) (2) Let the pupil close his eyes, stop the left ear with his finger. (3) Instruct him to say when he first hears the tick. (4) The observer stands at the pupil's right side, holding the watch *outside* the range of hearing and on a level with the pupil's ear. (5) He gradually brings the watch nearer to the pupil until the tick is distinctly heard. (6) The left ear should then be tested in the same manner. (7) The two distances and the hearing distance of the watch should be recorded in inches. Thus, if the hearing distance of the watch be 60 inches, and the pupil hears it with the right ear at 40 inches, and with the left at 25, the result should be recorded as

$$\text{R. } \tfrac{40}{60}$$
$$\text{L. } \tfrac{25}{60}$$

These fractions must *not* be reduced to their lowest term. The watch method is the better, but more troublesome. If used for children, it must be repeated two or three times at the same examination, as the statements are often unreliable. The same watch must always be used.

NOTE.—Inattention in children is often due to deafness. In all cases of deafness, the attention of the parent should be called to the necessity for treatment, especially if (*a*) there is a discharge of matter from the ears, or (*b*) the pupil seems always to have a cold, or (*c*) constantly breathes through the mouth instead of the nose. Observations as to hearing should be made twice annually.

Group B.—*Non-essential Observations.*

Other valuable observations are—(1) size of head; (2) span of arms; (3) length of trunk. These observations can be rapidly and easily taken; but in order to avoid over-burdening this circular, no instructions respecting them are here given. Any person desirous of carrying them out will receive full instructions by applying to the Secretary of the Committee,

PROFESSOR WINDLE, D.Sc., M.D.,
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Anthropometric Laboratory.—Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Dr. J. G. GARSON (*Secretary*), Mr. G. W. BLOXAM, Dr. WILBERFORCE SMITH, Professor A. C. HADDON, *and* Professor WINDLE.

THE Committee have to report that at the Nottingham meeting of the Association an excellent laboratory was provided for them in the University College buildings, where many of the Sections met. The services of a clerk were as usual placed at the disposal of the Committee, and by the kind permission of Mr. Francis Galton those of the superintendent of his laboratory at South Kensington were again available for measuring the members of the Association who visited the laboratory.

The schedule of observations and measurements made on each person examined included the sex, age, birthplace, residence, occupation, colour of eyes and of hair, profile of nose; height when sitting, kneeling, and standing; vertical projection from the vertex of the head to tragus, mouth, and chin; maximum antero-posterior length and transverse breadth of head, from which the cephalic index is obtained; the length and breadth of the nose, which gives the data for the nasal index; the nasio-mental length of face and the bizygomatic or maximum face breadth, from which the facial index has been calculated; length of upper limb from the acromion to the tip of middle finger; length of cubit and of hand (right); breadth of shoulders (bihumeral) and of hips (bitrochanteric); span of arms; weight in ordinary clothing; strength of grasp; vital capacity of the chest, strength of vision, sense of colour. This last was tested, in conformity with the recommendations of the Committee of the Royal Society on the subject, with coloured wools. The colour of eyes and hair was noted in accordance with Dr. Beddoe's method, which has been adopted for the Ethnographical Survey of Great Britain and Ireland.

The attention of the Committee has been called by Professor Edgeworth to the fact that the 'corrected mean' of each measurement as given in the reports of former years is not satisfactory, in that it assumes the dimension at the 25th and 75th grades—i.e. at the first and third quartile—(Q_1 and Q_3), to be more accurate than that at the 50th grade (i.e. Q_2). He has supplied them with a simple formula wherein the probable error at all three grades is taken into account. After several tests the superior accuracy of Professor Edgeworth's formula has been proved, and has been adopted in this report. His formula may be stated as follows:—

Corrected mean $= \frac{Q_1+Q_3-2Q_2}{3{\cdot}2}$. If the sum of Q_1+Q_3 is greater than $2Q_2$, the difference is divided by 3·2, and the result is added to Q_2; but if the sum of $2Q_2$ is greater than Q_1+Q_3, the latter is deducted from the former, the difference divided by 3·2, and the product subtracted from Q_2.

Since the close of the meeting the observations recorded during it have been carefully worked up, under the direction of the Secretary, after the plan which has been adopted in former years. Progress has also been made in amalgamating the results of all the Association laboratory statistics, which now amount to about 1,000.

The Committee are glad to be able to report that the measurements made in the laboratory of the Association for the last seven years have been of material service to Her Majesty's Government in connection with the anthropometric system of identification of criminals, which is about to be established in England. They have also been of use in comparing observations made on native races of different countries, and determining their deviation from or agreement with British people. The Committee seek to be reappointed, and to have the grant usually made to them continued.

The following are the results of the observations made on members of the Association who presented themselves at the laboratory during the course of the Nottingham meeting—

Number.—100 males and 55 females were measured, making a total of 155.

Age.—The age of the males whose measurements are included in this report varied from 17 to 75 years. Of these *five* were under 20 years; *fifteen* were 20 and under 30 years; *twenty-one* were 30 and under 40 years; *twenty-two* were 40 and under 50 years; *fourteen* were 50 and under 60; *thirteen* were 60 and under 70; *six* were between 70 and 75 years of age.

The ages of the females varied from 18 to 69 years. One was under 20 years (18); *twenty-one* were 20 and under 30; *twenty-three* were 30 and under 40; *four* were 40 and under 50; *three* were 50 and under 60; *three* were 60 and under 70 years of age.

DESCRIPTIVE CHARACTERS.

1. *Colour of Eyes.*—Dividing the colour of the eyes into the three divisions of dark, medium or neutral, and light, the observations were as follows:—

—	Light		Medium		Dark	
	No. of Cases	Per cent.	No. of Cases	Per cent.	No. of Cases	Per cent.
Males .	64	64	16	16·0	20	20·0
Females .	22	40	24	33·6	9	16·4

2. *Colour of Hair.*—Dividing the colour of the hair into similar classes, the following are the results:—

—	Light		Medium		Dark	
	No. of Cases	Per cent.	No. of Cases	Per cent.	No. of Cases	Per cent.
Males .	31	36·5	32	37·6	22	25·9
Females .	11	21·6	23	45·1	17	33·3

3. *Colour of Eyes and Hair combined.*—The following is the colour of hair found in connection with the three shades into which the colour of eyes is divided:—

Eyes	Light			Medium			Dark		
Hair	L.	M.	D.	L.	M.	D.	L.	M.	D.
Males . . .	26	25	4	4	5	5	1	2	13
Females . .	6	9	7	5	9	7	0	5	3

4. *Outline Form of Nose.*

—	Straight	Aquiline	Concave	High-bridged	Sinuous	Total
Males .	65	2	4	4	25	100
Females.	43	2	1	1	8	55

MEASUREMENTS.

1. *Stature.*—As in former years the stature was measured as the person stood in his boots, but the thickness of the heel has in each case been deducted so as to get as nearly as possible the true height. The stature of the males and females at the different quartiles, according to Mr. Galton's method, and the probable deviation (indicated by the letter Q), which is half the difference between the first and third quartile, are as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	1675·0	1719·0	1759·0	42·0	1717·7
Females . .	1573·5	1612·5	1656·8	41·6	1614·1

2. *Height when Sitting.*—This gives the length of the trunk of the body including the head and neck, and is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	875·9	897·7	924·0	25·9	899·1
Females . .	835·6	850·0	879·3	21·8	854·7

3. *Height when Kneeling.*—This measurement, along with the two previous ones, enables us to calculate the amount contributed to the height by the thigh, and by the leg from the knee downwards.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	1250·5	1276·7	1313·0	31·2	1279·8
Females . .	1188·3	1216·8	1245·9	28·8	1217·0

4. *Length of Lower Limbs.*—This is obtained by subtracting the sitting height from the stature ; the difference between these two measurements gives the amount contributed to the total height of the lower limbs.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	783·0	813·4	847·2	27·0	814·4
Females . .	714·4	760·9	797·2	41·4	757·7

5. *Length of Thigh Portion of the Lower Limb.*—This is obtained by subtracting the length of leg and height of foot from the length of the lower limbs :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	358·0	372·2	391·3	16·6	373·7
Females . .	342·4	358·5	385·3	16·3	361·8

6. *Length of Leg, including Height of Foot.*—This is obtained by subtracting the height when kneeling from the total stature :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	417·8	432·8	453·0	17·6	434·4
Females . .	374·4	396·5	411·3	18·4	394·2

7. *Proportion which the Limbs bear to the Trunk.*—This is obtained by reducing the length of the trunk of the body (including the head and neck) and the length of the limbs to percentage terms, the former being taken as 100. Each body and limb length is worked out by the following formula :

$$\frac{\text{Limb length} \times 100}{\text{Body length}},$$

which gives the Limb to Trunk Index. The several indices are then treated in the same manner as other measurements and indices, so as to show the index at the different grades :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	86·6	89·5	92·9	3·1	89·6
Females . .	84·3	88·6	91·8	3·7	88·3

The proportion which the limbs bear to the trunk in males of 1,828 mm. (6 feet) and upwards, of whom there are seven, at the 50th grade of this small series is 89·5, or exactly the same as at the 50th grade of the whole series of males. This series may be termed the tall class. In a series of six males whose stature is 1,613 mm. and under (5 feet 3½ inches), it is at the 50th grade 86·5, which is practically the same as at the 25th grade of the whole series. Hence the lower limbs in the series of short men are proportionately somewhat shorter to the body length than in the tall series ; but it cannot be said that in the latter series it is on account of the lower limbs being longer proportionately to the trunk length that the tall persons of the group owe their extra stature to. Both series are too small, however, to base any reliable conclusions upon.

8. *Proportions which the Trunk and Lower Limbs bear to the Stature.*—The proportions contributed by the different parts of the body which go to make up its total stature are as follows :—

	Males.	Females.
(*a*) Trunk with the head and neck . .	52·3 per cent.	53·0 per cent.
(*b*) Lower limbs from the level of the tuber ischia downwards . .	47·7 „	47·0 „
Total	100·0	100·0

The lower limb length, representing 47·7 per cent. of the stature in the males and 47 per cent. in the females, is made up as follows :—

	Males.	Females.
Thigh portion	22·2 per cent.	22·4 per cent.
Leg and height of foot . .	25·5 „	24·6 „
Total	47·7	47·0

9. *Vertical Projection or Height of the Head.*—The vertical distance from the vertex of the head to the under-surface of the chin is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	205·3	212·5	221·8	8·2	213·1
Females . .	202·1	210 2	217·5	7·7	210·0

10. *Vertical Length from Vertex to Mouth.*—This is measured to the line of junction of the upper and lower lips, and corresponds to the junction of the upper and lower incisor teeth :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	161·0	170·0	178·0	8·5	169·7
Females . .	160·7	169 4	177·6	8·4	169·3

By subtracting this measurement from the former the vertical depth of the chin is obtained. Using the corrected means of the two measurements for this purpose, the depth of chin in the males is 43·4 mm., and in the females it is 40·8 mm., or 2·1 and 2·5 per cent. of their statures.

11. *Cranial Height.*—This is represented by the vertical length from the vertex to a point opposite the middle of the tragus, which corresponds very closely to the upper border of the external auditory meatus. It is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	124·6	129·6	134·3	4·8	129·5
Females . .	122·9	127·8	131·5	4·3	127·4

12. *Maximum Antero-posterior Length of the Cranium.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	192·9	196·8	200 6	3·8	196·8
Females . .	180·7	183·7	188·2	3·7	184·1

13. *Maximum Breadth of Cranium.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	151·0	154·8	157·6	3·3	154·5
Females . .	144·6	147·7	149·4	2·4	147·3

14. *Proportions of the Head.*

(*a*) *Cephalic Index.*—The proportion of the breadth of the cranium to its length varies in the males from 69·6 to 87, and in the females from 72·6 to 86·6.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	76·0	77·9	79·8	1·9	77·9
Females . .	77·1	78·9	81·6	2·2	79·2

According to the International Division of the Cephalic Index the classification is as follows :—

Divisions	Limits	Males		Females	
		Number	Per cent.	Number	Per cent.
Hyper-brachycephalic . .	85–89·9	2	2·1	2	3 7
Brachycephalic. . . .	80–84·9	26	27·1	22	40 7
Mesaticephalic	75–79·9	61	63·5	28	51·9
Dolichocephalic . . .	70–74·9	6	6 3	2	3·7
Hyper-dolichocephalic . .	65–69·9	1	1·0	0	—
Total . . .	—	96	100·0	54	100·0

(*b*) *Module of the Cranium.*—This is obtained by adding its length, breadth, and height together, adding to the product 15 mm. in the case of males and 13 mm. in the case of females, to represent the projection of the cranium from the meatus auditorius to the basion, and dividing the sum by 3. It is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	162·0	164·9	168·1	2·7	164·5
Females . .	153·8	157·1	159·5	2·8	156·9

(*c*) *Head Breadth-height Index.*—This indicates the relation which the maximum breadth of the cranium bears to the vertical projection of the head, the latter being taken as 100. Estimated from the corrected means of these measurements it is 72·5 in the males and 70·1 in the females.

(*d*) *Maximum Cranial Length to Vertical Height of Head Index.*—The vertical height of the head (vertex to chin) being taken as 100, the index is in the males 90·9 and in females 87·6.

(*e*) *Vertical Cranial Height to Vertical Head Height Index.*—The latter being taken as 100, the height of the cranium in relation to it is 60·8 in the males and 60·1 in the females.

(*f*) *Vertical Height of Head to Stature.*—The canon of proportion of the vertical height of the head to the total stature of the body (the latter being taken as 100) is 12·4 in the males, 13·0 in the females.

(*g*) *Vertical Height of Cranium to Stature.*—In the males it is 7·5, and in the females 7·9.

(*h*) *Vertex to Mouth Length as compared with Stature.*—In the males this is 9·9 and in the females 10·5.

15. *Nose Length.*—The length of the nose from the root to the lower angle varies from 44 mm. to 66 mm. in the males, and in the females from 41 mm. to 55 mm.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	49·4	52·2	54·0	2·3	52·5
Females . .	45·4	47·8	50·9	2·7	48·0

16. *Nose Breadth.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	29·1	31·7	33·7	2·3	31·5
Females . .	26·1	27·8	29·8	1·8	27·7

17. *Nasal Index.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	51·2	56·6	61·4	5·2	56·4
Females . .	49·1	53·9	59·9	5·4	54·3

18. *Face Length.*—This is measured from the root of the nose at the same point as that from which the length of the nose starts to the under-surface of the chin.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	108·8	113·6	119·9	5·5	114·0
Females . .	105·3	110·8	115·4	5·1	110·6

19. *Face Breadth.*—Measured between the external surfaces of the zygomatic arches at the vertex of each arch. It is therefore the maximum breadth of face.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	120·8	126·2	133·4	6·4	126·5
Females . .	118·2	123·8	129·0	5·4	123·7

20. *Face Index,* or the relation which the face breadth bears to the face length, the latter (nasio-mental length) being taken as 100.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	105	109·3	114·0	4·5	109·4
Females . .	106	110·5	118·5	6·2	111·0

21. *Length of Upper Limb.*—Measured from under the acromion process to the tip of the middle finger in a straight line parallel with the long axis of the arm.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	717·8	739·9	767	24·6	741·6

Owing to difficulties connected with dress this measurement was not taken in females.

22. *Length of Cubit.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	443·4	458·2	475·0	15·3	458·5
Females . .	402·7	417·0	435·5	16·4	418·3

23. *Length of Hand.*—This is ascertained by placing a steel measuring tape round the wrist so that the upper border of the tape crosses immediately below the tips of the styloid processes of the radius and ulna, and measuring from the upper border of the tape, midway between each side of the wrist, to the extremity of the middle finger.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	187·3	192·9	198·6	5·6	192·9
Females . .	165·9	174·3	181·2	7·6	173·9

24. *Proportions which the Upper Limb bears to the Stature and to its different Segments, and the mean lengths of the latter.*

(*a*) The proportion which the whole upper limb bears to the stature in the males is 43·2 per cent.

(*b*) The proportion which the length of the cubit bears to the stature is 26·7 per cent. in the males and 25·9 per cent. in the females.

(*c*) The lengths of the three segments of the upper limb as obtained by subtraction from the corrected means of the last three measurements (21, 22, and 23) are as follows :—

	Males	Females
Upper arm	283·1	—
Forearm	265·6	244·4
Hand	192·9	173·9

(*d*) The proportion which the length of the upper arm bears to the stature is 16·5 per cent. in the males.

(*e*) The proportion which the length of the forearm bears to the stature is 15·4 in the males and 15·1 in the females.

(*f*) The proportion which the length of the hand bears to the stature is 11·2 in the males and 10·8 per cent. in the females.

(*g*) The proportion which the length of the forearm bears to that of the upper arm (the latter being taken as 100) is 94·5 per cent. in the males.

(*h*) The proportion which the length of the hand bears to that of the forearm (the latter being taken as 100) is 72·6 per cent. in the males and 71·1 in the females.

25. *Span of Arms.*—This is measured across the back, while the arms are extended at right angles to the long axis of the body.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	1700·1	1757·5	1815·6	57·7	1757·7
Females . .	1546·7	1593·2	1648·0	50·6	1595·7

26. *Maximum Bihumeral or Shoulder Breadth.*—This gives the greatest breadth of the shoulders, and is measured between the most prominent external surfaces of the deltoid muscles.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	395·6	408·5	422·2	13·3	408·6

27. *Maximum Bitrochanteric or Hip Breadth.*—This is the greatest width from the external surface of the trochanter of the one femur to that of the other measured while the subject stands erect with the fee close together and parallel.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	284	297·5	312	14·1	297·8

28. *Proportions of Shoulder and Trochanteric Breadths to the Stature and to one another.*—(*a*) The proportion which the maximum breadth of shoulder bears to the stature calculated from the corrected means of these measurements is 23·8 per cent., while that of the trochanteric breadth to the stature is 17·3 in the males. Topinard gives these indices in Parisians as 22·9 and 18·5 respectively. (*b*) The proportion which the trochanteric or maximum hip breadth bears to the maximum shoulder breadth (the latter being taken as 100) is 72·9 per cent. Topinard gives this index in one series of 100 Parisians, measured by A. Bertillon, as 83, and in a second series of 40 individuals as 80·8 per cent.

29. *Weight.*—The figures of weight are given in English pounds and tenths of a pound.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	133·8	147·5	163·6	14·9	148·2
Females . .	106·8	119·0	129·3	11·2	118·4

30. *Strength of Grasp.*—The results here given are the *mean* of the right and left hands, and *not* the strongest grasp with either hand as frequently recorded, and is expressed in pounds and decimals thereof.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	50·0	71·3	79·8	8·4	71·3
Females . .	38·7	46·2	57·7	9·5	47·2

In the males the right hand is the stronger in 64 cases; that is, in 67·4 per cent. The left hand is the stronger in 22 cases; that is, in 23·1 per cent. Both hands are of equal strength in 9 cases; that is, in 9·5 per cent.

In the females the right hand is the stronger in 37 cases (67·3 per cent.); the left hand is the stronger in 14 cases (25·4 per cent.); the strength of both hands is equal in 4 cases (7·3 per cent.).

31. *Vital Capacity of the Lungs.*—This was ascertained by means of Stanley's spirometer, and is given in cubic inches, to which the instrument is graduated.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	168·4	201·6	233	32·2	201·0
Females . .	120·6	136·8	150	15·0	136·1

32. *Vision.*—The strength of vision was tested by means of Snellen's test-types at a distance of six metres from the eye, each eye being tested separately. While one eye was being tested the other was kept open and a black card was held over it, so that the type could only be seen by the eye being tested.

Of the 96 males tested only 32, or 33·3 per cent., had normal vision;

that is to say, were able to read with both eyes No. 6 type. Of the 96 males, 39 were 46 years of age and upwards. The vision of the females was better, as 30 out of 55 tested, or 52·7 per cent., had normal vision; but, on the other hand, only 8 of the number tested were 46 years of age and upwards. In a large number of cases in both sexes, the vision in one eye was more defective than in the other.

33. No cases of colour blindness were discovered in either males or females.

The following table gives the canon of proportion of the several parts of the body in relation to the stature, the latter being taken as 100. In this collected form it will be found more convenient for comparison with those of artists.

Canon of Proportion of the Body.

		Males	Females
Trunk, including head and neck, to the level of the *Tuber Ischia*		52·3	53
Lower limbs from the level of the *Tuber Ischia*		47·7	47
Total		100	100
Upper limbs (acromion to end of medius finger)		43·2	—
Head vertex to chin		12·4	13
„ „ tragus		7·5	7·9
„ „ mouth		9·9	10·5
Trunk and neck		39·9	40
Thigh	Males 47·7, Females 47	22·2	22·4
Leg and height of foot		25·5	24·6
Upper arm	43·2, —	16·5	—
Fore arm		15·4	15·1
Hand		11·2	10·8
Cubit		26·7	25·9
Shoulder breadth		23·8	—
Hip breadth		17·3	—

On the North-Western Tribes of Canada.—Ninth Report of the Committee, consisting of Dr. E. B. TYLOR, Mr. G. H. BLOXAM, Dr. G. M. DAWSON, Mr. R. G. HALIBURTON, *and* Mr. H. HALE.

THE Committee were appointed, as in former years, to investigate the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada.

In consideration of the difficulties and delays in completing their work of Canadian exploration and editing its results the Committee have been reappointed for this year, without a grant of money. They are thus enabled to send in the following report, by Dr. Franz Boas, on the 'Tribes of the Lower Fraser River,' in continuation of his previous communications. This, however, does not exhaust the anthropological information in course of being obtained and put in order by the Committee, who hope to bring their investigations to a close during the present year, and to report finally to the Meeting of the Association in 1895.

The Indian Tribes of the Lower Fraser River. *By* DR. FRANZ BOAS.

In the sixth report of the Committee I described the customs of the Lku'ñgEn, the most southern group of the Coast Salish living on British territory. The northern neighbours of the Lku'ñgEn, who will be described in the following pages, speak the K·auētcin (Cowichan) language. This dialect of the Coast Salish is spoken on Vancouver Island from Saanitch Inlet to Nonoos, on the islands north of Saanitch Peninsula and on the Lower Fraser River as far as Yale. The language as spoken on Vancouver Island and on the mainland shows slight dialectic differences, the most striking ones being the general substitution of *l* for *n*, and of *ă* for *ā*, on Fraser River. I have given elsewhere some notes on the tribes of Cowichan River and of Nanaimo which belong to this group.[1] Therefore I confine myself in the following pages to remarks on the tribes of the mainland, whom I studied in the summer of 1890.

The Cowichan of the mainland are divided into fourteen tribes, each forming a village community. The inhabitants of each village are believed to be the descendants of one mythical personage. I give here a list of tribes, their villages, and the names of the mythical ancestors :—

Tribe.	Villages.	Ancestor.
1. QmE'çkoyim.	Mā'lē, on North Arm of Fraser River.	Pä'pk·EltEl (flag).
2. K·oă'antEl.	Stcuwā'cEl, near South Arm of Fraser River. Tcē'tstlEs, at New Westminster.	K·alE'tsEmEs (badger).
3. K·ē'ētsē.	SElts'ā's, at head of Pitt Lake, summer village. Cuwā'lEçEt, at lower end of Pitt Lake, winter village.	Tsatā'sEltEn.
4. Mā'çQui.	Mā'mak·ume, above Langley, on left bank. Kōkoaē'uk·, on Sumass Lake.	Sk·Elē'yitl (beaver).
5. LEk·'ä'mEl. (NEk·'ă'mEn).	Lā'qauI, summer village. Skuyā'm, winter village.	IālEpk·ē'lEm (sturgeon).
6. Tc'ilEQuē'uk·.	Ts'uwä'lē, Qē'lEs (on upper part of Chilluwak River).	T'ē'qulätca.
7. StsEē'lis.	StsEē'lis.	Ts'ā'tsEmiltQ.
8. Sk·au'ēlitsk.	Sk·au'ēlitsk, Skuā'tats.	K·ultē'mEltQ.
9. PElā'tlq.	Tcā'tcōHil, Tcē'iām.	Qä'latca.
10. Pā'pk'um.	Pā'pk'um.	Aiuwä'luQ (mountain goat).
11. SIyi'ta.	SQuhä'mEn (Agassiz).	Autltē'n.
12. Ēwā'wus.	SqE'ltEN (two miles above Hope).	
13. Ts'akuä'm.	CilEk'uā'tl (Yale), Cuwulsē'lEm.	Suwilā'siä.
14. QElā'tl.	Asilā'o.	Qē'lqElEmas.

The tribes above Skuyā'm are collectively called Tē'it = those up river. The tribal traditions tell that Qäls, the deity (see p. 463), met the ancestors of all these tribes and transformed them into certain plants or animals which generally abound near the site of the winter village. For instance, Mā'lē is well known for the great number of flags growing in the slough near the village, mountain-goats are found not far from Pā'pk'um, and so forth. In many cases the ancestor is said to have been transformed into a rock of remarkable shape or size, which is found not far from the village. Thus T'ē'qulätca, Qä'latca, and Autltē'n are still shown. I do not understand that the tribe itself claims any relationship with these animals or plants, but nevertheless these ideas must be con-

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[1] *American Anthropologist*, 1889, p. 321; 'Zur Ethnologie von Britisch-Columbien,' Petermann's *Mittheilungen*, 1887, No. 5; *Verhandlungen der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte*, 1891, p. 628.

Qā'wulEts mar
Sk·au'ēlits.

SHā'lēya marrie
StsEē'lis.

Ts'ā'tsEmiltQ m
Ts'ā'tsEluwit m
StsEē'lis.

sue doubtful.

Si sue doubtful.

torica sue unknown.
Stseē sue unknown.
T
h
q
g

ver.

sidered as an interesting phase in the development of totemism. Some of the more complicated institutions of this class may have originated from similar concepts.

A few of the tribes have certain privileges not shared by the others. This is particularly the case of the Sqoā'eqoē, the curious feathered head with prominent eyes which I have described on a former occasion ('Proc. U.S. National Museum,' 1888, p. 212), and which is the crest of certain families among the Çatlōltq (Comox) and Nanaimo. This crest belongs originally to several tribes of the mainland. The Sqoā'ēqoē are believed to be a supernatural people living in lakes. When a person succeeds in bringing one of them to the surface of the water he and his descendants acquire their protection and assume their figure as the crest of their family. It belongs to the Sk·au'ēlitsk, Ēwā'wus, and Ts'akuä'm. The Sk·au'ēlitsk tell that their ancestor, K·ultē'mEltQ, had two sons and two daughters. The latter went fishing every morning. One day they caught first each a trout. Later on they felt that they had caught something heavy, and on hauling in the line saw the prominent eyes and the long feathers of the Sqoā'ēqoē. They called their father, who carried him home, but soon the being disappeared and only his dress remained. K·ultē'mEltQ's descendants married in the Stseē'lis, QmE'çkoyim, Snanai'muQ, Sk·oā'nic, K·auētcin, and Çatlōltq tribes, and thus the use of the Sqoā'ēqoē was disseminated. The Ēwā'wus tell that an orphan boy went swimming and diving every day in order to get strong. One day he made a fire near a lake and accidentally spat into the water. When he dived he was almost drowned. At the bottom of the lake he found the Sqoā'ēqoē trying to heal a sick girl of their people whom the saliva had hit and made sick. The boy washed her and she recovered at once. Then they gave him the Sqoā'ēqoē. The Ts'akuä'm say that their ancestor found the Sqoā'ēqoē.

In the above list of tribes the Kuī'kōtlEm of Tcanē'tcEn have been omitted. They are descendants of slaves of TlpElk·ē'lEn, chief of the K·oā'antEl, who established a fishing station at the site of the Kuī'kōtlEm village, and ordered part of his slaves to live at this place. Five generations ago, when wars were raging on this part of the coast, they became free, and continue to occupy their old village. They are, however, not considered as equals of the other tribes, and never owned any land. They do not claim to be the descendants of a mythical ancestor. Their present chief is named T'E'lk·Es.

The tribal traditions of these people are evidently founded on historical events. This becomes particularly clear in the cases of the Stseē'lis and of the Tc'ilEQuē'uk·. The tradition of the former says that Ts'ā'tsEmiltQ, the ancestor of the tribe, was sent down to StsEē'lis from heaven. One of his descendants built a fish weir on one of the tributaries of Harrison River, and thus deprived another tribe on the upper reaches of the river of its food supply. K·ulk·E'mEHil, chief of this tribe (who were descendants of the marten and of the mountain-goat), sent his sons down the river to see why the salmon did not come as usual. They found the weir and tried to destroy it, but were captured by Ts'ā'tsEmiltQ's sons, who invited the tribe to descend from the hills and to live in StsEē'lis. They followed the invitation, and ever since have lived with the StsEē'lis.

According to tradition the Tc'ilEQuē'uk· spoke, until the beginning of this century, the Nooksak language, which prevails farther to the south. The tribal myth states expressly that the tribe was originally a mountain

tribe living on the upper reaches of Chilluwak River, a und that they
migrated down the river.

Evidently historical traditions are preserved relatively fa ithfully by
these tribes. This is shown particularly clearly in the care whic h is taken
in preserving the pedigrees of chiefs. I obtained one of these e mbracing
eight generations. I reproduce here that part of the same whic h I have
been able to corroborate by repeated inquiries among different bra ches of
the family. The chief of a tribe always takes the name of the pre ceding
chiefs, sometimes that of the mythical ancestor, which accounts fo the
recurrence of the same names. When a person has relatives in two
villages, he is known by two names. In each village he is called b by a
name belonging to the village. Thus 'Captain George' is known as
Ts'ā'tsᴇmiltq in Stsᴇē'lis, as Qä'wulᴇts in Sk'tsā's, north of Harrison La ke.

TABLE II.

- ♂ Qä'wulᴇts marries Qᴇē'tsuwot of Lku'ñgᴇn.
  - ♂ Qä'wulᴇts marries Ckitltā't of Asilā'o.
    - ♂ K·ᴇlā'wulᴇts marries Qᴇ tsā'mat, Sᴇlā'sauwot o Lᴇk·'ā'mᴇl, daughter of Qᴇltsā'm.
    - ♀ Cʜē'itla (see Table I.).
    - ♀ Skutsā'stᴇlāt married to Lᴇmlᴇ'matsᴇs, a Qmᴇ'çkoyim.
  - ♂ Sʜā'lēya marries Tcᴇlā'quwot of Sk'tsā's, daughter of K·ä'uwa.
    - ♂ K·ä'uwa married at Port Douglas.
    - ♂ Ts'ē'k·taqᴇl marries Ts'ä'itl of Asilā'o.
    - ♀ Sʜalā'p'ēya married to K·stā'laqᴇn of Lillooet.
    - ♀ S'ēyi'tla married to Tsᴇ'lpᴇltq of Cowichan.
  - ♂ Gyi'ᴇmᴇt marries Ts'ᴇlā'quwot, daughter of K·ä'uwa of Sk'tsā's, sister of the above.
  - ♂ Qē'lqᴇlᴇmas marries Sʜalā'p'ēya of Sk'tsā's.
  - ♂ Ts'ᴇtsā'mᴇt marries Ts'ā'mᴇk·oat of Sk'tsā's.

These pedigrees are also of some interest, as they show the mode of intermarriage among the tribes of these regions, and as they bring out the extermination of whole families very clearly. It appears that the mortality of children is the principal cause of diminution, much more so than decrease in the number of children to each family.

It appears that the tribes of Harrison River intermarry with the Lillooet tribes north of Harrison Lake. These tribes are organised essentially in the same way as those of Fraser River, each village community claiming a common ancestor. Thus the ancestor Qä'wulᴇts of the Sk'tsā's is said to have been a bear, who assumed the human form and built a town; the Pōtᴇ'mtᴇn claim to be the descendants of a stone hammer and of chips which married two women.

I do not need to describe the houses of these tribes, as they are the same as those of the Lku'ñgᴇn. Above Harrison River subterraneous lodges like those of the Shushwap were sometimes used, although the large wooden houses were more common. I was told that the chief of Sk'tsā's, north of the upper end of Harrison Lake, owned a house with painted front. A carved pole with the figure of a raven on top stood in front of the house.

The mode of life, fishing, use of canoe and implements do not differ materially from those of the Lku'ñgEn.

Customs referring to Marriage and Death.

The marriage customs are almost the same as those of the Lku'ñgEn. When a young man desires to marry a certain girl he informs his parents. After having gained their consent he goes to the house of the girl's father and sits down outside close to the door. At night he returns home. For three days he continues to sit there silently. Then the girl's father, knowing his intentions, invites many people and has mats and blankets spread near the fire. He sends two old men to invite the young man, who enters the house following this invitation. He is seated on a mat and a pile of blankets is placed near him. His father, who kept a watchman near the house, is informed at once, when the young man is invited to enter the house. He sends four blankets to the two old men who invited his son. The girl's mother meanwhile prepares a large dish filled with choice food, which her husband presents to the young man. The latter eats a little and returns home. Then his father sends presents of blankets and other valuables to the girl's father. This is continued for three or four days, when the girl's father is asked if he is willing to give the girl in marriage to the youth. The consent being given, the groom's father asks all his relatives and followers to assemble on the following morning in order to fetch the bride. They load their canoes with food and blankets and start for the bride's house. Meanwhile her house is cleaned, and after some time the canoes land, the blankets are carried up to the house, and after the purchase of the girl has been settled, the dishes filled with food are carried to the house. The fathers exchange promises of kindly treatment of the couple, in the course of which the groom's father states that he paid a high price for the girl, because he wants to prevent a separation of the couple. Then the visitors return to their canoes. After some time four old men lead the bride to the canoe, holding her by her blanket. Among the tribes entitled to the privilege of using the Sqoā'ēqoē, one of these men wears the Sqoā'ēqoē mask. He follows the girl. Another one carries a rattle. They walk over mats or blankets spread from the door to the landing-place. After they have delivered the bride to the groom, they are paid two blankets each by the groom's father. The latter distributes blankets repeatedly among the bride's relatives, first in her house, later on before leaving, from the canoe, an old man of his family delivering an oration meanwhile. Then blankets are given to the chief of the bride's family, who distributes them. Before the visitors leave, the bride's father presents blankets to the groom's father, who distributes them among his people. When the party arrive at the groom's house, his parents, uncles, and aunts receive the young wife with presents. After the marriage the two families feast each other frequently.

Sometimes chiefs betroth their children in early youth. They bind themselves by exchanging presents. In this case the ceremonies are somewhat simpler. The parents guard their children with particular care. When they are old enough to be married the youth assembles many of his friends and sends word to his bride's parents, stating when he intends to come. At the appointed time he lands and brings many presents, food and blankets, to his bride's father, which the latter distributes among his family. The bride's father presents one blanket and some food to each of his visitors, who depart, taking the bride along. As a rule, the latter follows her husband. When she gets old and sickly she often returns to her own village, in order to be buried with her relatives. Only when some of her children preceded her in death she is buried with them. Although chiefs were in the habit of taking wives in other villages, marriages among families of the same village were not forbidden.

The customs of the Lillooet tribes above Fort Douglas were different. Girls when of age slept with their mothers. When a man intended to marry a girl he crept stealthily up to her bed and tried to take hold of her heel. The meaning of this action is said to be founded on the fact that the heel of the woman is near her private parts when she squats, as Indian women are in the habit of doing. She informs her father at once that a certain man has taken hold of her heel, and he must marry her. She follows the young man to his parents. As soon as they arrive, the groom's mother fills many baskets with boiled food and sends them to the bride's mother, while the male relatives of the youth carry blankets and other presents to the girl's father. They are invited to sit down and given a feast. The bride's father sends the groom bows and arrows and shoes that he may be able to hunt for his wife. The groom's mother gives her dentalia for her hair, earrings, and bracelets. After the young man has killed a number of deer he carries them, helped by his friends, to his wife, and asks her to take them to his father-in-law. She asks several women to help her, and they take the meat to her father's house. The young couple and the parents continue to exchange presents for several years.

I have not learned anything of importance regarding customs referring to birth. The names are given by paternal and maternal relatives, and each family and tribe has its own names. For this reason each person has several names, and is called in each village differently: in his mother's village by the name of the maternal relative after whom he is called; in his father's village by the name of the paternal relative whose name he has received.

The ancient burial customs were described to me as follows:—Each family had its own burial-place, which consisted of a large box or a small house built on piles. This building was erected by members of the family only, and all those who helped to make it received ten blankets in payment from the chief. All the members of a family were placed in this box or house. The first one to die was placed in the north-east (or north-west) corner, the face turned eastward, the body lying on its left side. The next one was placed south of the first, and so on until one row was filled. Then a new row was begun, and the dead ones were all deposited in the same box until it was full. Persons who were very fond of each other were often placed side by side. When the building was full, the bones were taken out, put on new blankets, cleaned, and placed in a new box. Evidently they were piled up in one corner, as there was room for additional burials in the new box. After the bones had been replaced three or four times, they were not taken out again, but a new house was erected. Chiefs and common people were buried in separate houses or boxes.

The burial ceremonies were as follows:—Immediately after a death had occurred, the corpse was prepared for burial by an old man, who had first to chew cedar leaves as a protection against the dangerous influences of contact with a corpse. He washed the body, painted it red, put on the bracelets and other ornaments of the deceased, doubled it up, so that the knees touched the chin, and wrapped it in blankets or mats. A young man must not do this work, as he would die soon. When the deceased had been a chief or a personage of importance, all the neighbouring tribes were invited to take part in the following ceremonies. After they had assembled, the wife of the chief mourner gave each water to wash his face. Then the guests were given a feast, and on the following day the corpse was placed in a canoe and removed to the burial-ground, where it was deposited not far from the scaffold which served for the final burial. The guests returned to the house, and were given again water to wash their faces. For four days the body was left standing, that the dead might be able to return in case he should resuscitate. Then, on the fifth day, before sunrise, and before partaking of any food, the mourners and guests returned to the burial-ground. If the deceased owned the Sqoā'ēqoē, the latter was carried there by an old man, who received payment for this service. Slaves, blankets, and other property of the deceased were taken along. Four old men put the body into the house. They must fast until late in the evening, when the chief mourner gave a feast. The slaves were killed and placed on top of the burial-house, where the blankets were also deposited. Other objects were tied to branches of trees near the burial-ground. Only those objects which the deceased valued most highly were placed in the house. It is stated that the people were allowed to take away all those objects which were deposited near the box. In the evening of the same day the chief mourner gave a feast, during which everything was burned that belonged to the deceased. An old man threw the objects into the fire. The guests were presented with blankets, and returned home. If the deceased was a chief, his son fasted and bathed in ponds on the mountains, until he believed that he had seen a spirit which gave him supernatural powers. Then he began to collect property. When he had gathered a large amount, he invited all the neighbouring tribes, and gave a feast which lasted for four days. Then he selected two old men, who had to tell the people that he was going to assume his father's name. The young man, with his wife and children, stood on the scaffold in front of their house, and while the woman and children were dancing there, the old men delivered orations, and the young chief distributed blankets among his guests, throwing the blankets down from the scaffold.

It does not appear that it is forbidden to mention the names of deceased persons.

The burial customs of the Lillooet are somewhat different. I was told that the dead are placed 'so that their backs never turn toward the sun.' They are laid on their left sides, the head westward, the face southward. Old men are hired to paint the face of the deceased, and they deposit the body in a cave as described before. The weapons and implements used by the deceased are buried near the grave, but his friends are said to be permitted to keep some of his implements, provided the son consents.

HUNTING AND FISHING.

Man and all animals which are hunted are considered one great family. The porcupine is called the eldest brother, and is considered the strongest. Next in rank is the beaver, third the *ts'etspek·* (?), fourth the buffalo, fifth the mountain-goat, sixth the black bear, seventh the elk, eighth the marten, ninth the eagle. The mink is one of the very last among the brothers. Accordingly there are a number of restrictions and regulations referring to hunting.

When a porcupine is killed, the hunter asks his elder brother's pardon, and does not eat of the flesh until the ensuing day.

The mountain-goat hunter fasts and bathes for several nights. Then early in the morning he paints his chin with red paint, and draws a red line over his forehead down to the point of his nose. Two tail feathers of the eagle are fastened to his hair. These ornaments are believed to enable him to climb well.

The elk hunter adorns his hair with coal, red paint, and eagle-down. His chin is painted red, and two red lines are drawn horizontally across his face, one passing between nose and mouth, the other over his eyes.

Those who go to catch sturgeon bathe in a pond early in the morning. They rub themselves with bundles of a plant called *tsk'utlptis* until they bleed. Then they smear their bodies and faces with red paint, and strew white eagle-down on their heads. Each winds a thread made of mountain-goat wool around his head, and another one around his waist. A woven blanket of mountain-goat wool is painted red, and put on. The fish is caught in the following manner:—Two canoes are allowed to drift down river, a net being stretched between them. The oarsmen are seated on the outer sides of the canoes only. The net is stretched between two poles. As soon as a sturgeon is caught, the two canoes approach each other, and the net is wound up by means of the poles. While this is being done the 'sturgeon hunter' sings, and by means of his song pacifies the struggling sturgeon, who allows himself to be killed. The fisherman must distribute the sturgeon among the whole tribe, each person receiving a portion according to his rank. I was told that the Tc'ilEQuē'uk· do not catch sturgeon. This is probably due to their recent immigration to the Fraser River Delta.

The origin of the various designs of ornamentation used by hunters is made clear by the following story, which was told to me by George StsEē'lis, chief of that tribe. His grandfather, who was chief at Sk'tsā's, accompanied another man on a bear hunt. After two days' search they found the tracks of a black bear, and soon their dog scented the cave in which the bear was asleep. They tried to stir him up by means of long sticks. When he did not come they made a large fire at the entrance of the cave in order to smoke him out. Still he did not come. Then the hunters thought he was dead, and the companion of George's grandfather crawled into the cave. At once the bear took hold of his head and dragged him into the cave. The grandfather, on seeing this, fainted, and remained in a swoon for three days. When he awoke, he saw his companion coming out of the cave. He told him: 'When I was hauled into the cave, the bear took off his bearskin blanket, and I saw that he was a man. He bade me sit down, and told me: Henceforth, when you go to hunt bears, paint the point of your arrow red, and draw a red line along its shaft. Draw a line of mica across your face from one temple to the other across your eyes, and one line of mica over each cheek vertically downward from the eyes.' When the hunters reached home they told their experiences. Henceforth the people followed the instructions of the bear-man, and were successful when hunting bears.

The panther is not hunted by the StsEē'lis, because he is supposed to help the people when hunting deer. In reference to this belief, George Stsᴇē′lis told me that his grandfather and a man named A′m′amaltsen went hunting in their canoes on Harrison Lake. Soon they saw a number of deer crossing the lake. A′m′amaltsen went in pursuit, but George's grandfather stopped on hearing a panther call him. He went ashore, and immediately a panther jumped aboard and asked to be carried across the lake. The man obeyed, and when he had almost reached the other side, the panther jumped ashore, crying Hum! hum! He jumped up the mountain, and soon a great number of deer came down the hills, which the panther had sent. Ever since that time he has helped the Stsᴇē′lis in hunting deer.

These tales are interesting, particularly on account of their close similarity to the traditions of the animal totems of America.

A great number of restrictions and regulations refer to the salmon. These rules are similar to those observed among the other coast tribes. When the fishing season begins, and one of the fishermen catches the first sockeye-salmon of the season, he carries it to the chief of his tribe, who delivers it to his wife. She prays, saying to the salmon: 'Who has sent you here to make us happy? We are thankful to your chief for sending you.' Then she begins to cut it. She commences at the tail, holding the latter with her foot, and cutting along the belly towards the head. After having reached the middle of the fish she must rise, go to the head, hold the latter with her foot, and make another cut from the head along the belly towards the middle of the fish, thus completing the whole cut. She is forbidden to turn the salmon. Then the fish is roasted on a frame placed over the fire. After one side is done, it is turned over. The skin and the bones must not be removed. Then the whole tribe is invited. The plant *pē′pek·oi* and pewter grass are placed in a basket, rubbed, and a decoction is made of these plants, which is used as a medicine 'for cleansing the people.' The guests drink this decoction, and then every member of the tribe receives and eats part of the fish. Widows, widowers, women during their menses, and youths must not eat of the salmon. Even later on, when the fish are numerous, and these ceremonies are dispensed with, they are not allowed to partake of fresh salmon, but eat dried salmon only. The sockeye-salmon must always be looked after carefully. The bones must be thrown into the river. It is believed that then they will revive, and return to their chief in the west. If not treated carefully, they will take revenge, and the careless fisherman will be unlucky.

Religion.

Man is believed to have four souls. The main soul is said to have the shape of a mannikin, the others are the shadows of the first. In disease either the lesser souls, or the main one, leave the body. Shamans can easily return the shadows, but not the main soul. If the latter leaves the body the sick one must die. After death the main soul goes to the sunset, where it remains. The shadows become ghosts (*pālek·oi′tsa*). They revisit the places which the deceased frequented during lifetime, and continue to do the same actions which he did when alive. Souls are believed to be taken away by the rising sun, which thus produces disease. They may be recovered by shamans. The belief of the identity of the shadow and the lesser soul accounts also for the custom that nobody must let his shadow fall on a sick shaman, as the latter might take it, and thus replace his own lost soul.

There are two classes of shamans: the witches (Si′ōwa, called Sçō′wa by the Lillooet) and the Sᴏulä′m. The difference between the two has been described in the sixth report of the Committee in the account of the beliefs of the Lku′ñgᴇn. The witch can see the wandering soul, but she cannot return it. The Sᴏulä′m acquires his art by fasting and ceremonial cleansing, which consists principally in bathing and vomiting. This is continued until he has a revelation. In his incantations he uses rattling anklets and bracelets around wrists and above elbows, which are made of deer hoofs and bird claws. When it is the object of his incantation to recover a lost soul, he covers himself with a large mat, and begins to dance, stamping energetically, until he is believed to sink into the ground as far as his belly. While the incantation continues, which may be for one or even two days, the sick one must fast. Then the shaman lies motionless while his soul goes in pursuit of that of the patient. When it returns with the lost soul, the shaman begins to move again, and shouts. His cries refer to imaginary incidents of his journey and to dangers of the road. As soon as he begins to move, his wife places a cup of water near him, which she heats by means of hot stones. Then he rises, holding the soul in his clasped hands. He blows on it four times and sprinkles it four times with the warm water. After having warmed it by these means, he puts it on the sick person's head. Then it enters the body through the frontal fontanelle. He presses on it four times and rubs it down the body, which the soul fills entirely. The shaman blows some water on the chest and back of the sick person, who is then allowed to drink, and after some time to eat. The soul may escape while the shaman is trying to put it into the body of the patient. Then he must go once more in pursuit. Sometimes the shaman sees the main soul breaking into several parts. The owner of the broken soul must die.

The sun plays an important part in the beliefs of these tribes. It has been stated that he carries away souls. He is also believed to send dreams and to give the fasting youth revelations. After continued fasting in the solitude of the mountains, the sun revealed to him the supernatural power which was to be his helper. George Stsᴇē′lis told me that his grandfather was instructed by the sun to take a large piece of bone and to carve the design of a mouth on it; this was to protect him in war. When he was wounded the bone sucked the blood from his wounds and vomited it, thus curing him. Once in a battle fought with the Lillooet he was wounded in the abdomen. He escaped on the ice of the lake, dragging his entrails. He replaced them and bandaged himself with cedar-bark. By the help of his bone implement he recovered.

The sun told warriors before the battle if they would be wounded. After having received such a warning they demanded to be buried, with their legs stretched out, as it was believed that the sun might restore them to life. By continued fasting warriors acquired the faculty of jumping high and far, which enabled them to escape the missiles of their enemies. This was considered essentially a supernatural power, and one warrior was said to have jumped as far as eighteen fathoms. Warriors went naked and were forbidden to eat before or during an attack. Their bodies and faces were painted red, and black spots or stripes of various designs were put on their faces. They wore head ornaments of feathers

On the upper reaches of Fraser River the custom of cutting off the heads of the slain did not prevail, but the victor took the head ornament of his killed enemy. The mode of warfare was the same as everywhere on the coast: unexpected attacks on the villages of the enemies just before the dawn of the day.

Among other mythical personages I mention Qäls, the great transformer, who is often described as the principal deity. I have treated this subject in another place.[1] The country of the sockeye-salmon is in the sunset. Their chief is a powerful being, and takes care that the rules referring to the treatment of salmon are observed. The souls of the killed salmon return to him and are revived.

The East Wind, Cā'tᴇts, lives in the sunrise; his brother, the West Wind, in the sunset. The east wind and the west wind are their shadows (or souls?). When the east wind is blowing a long time, the Indians try to appease it. Early in the morning they take sockeye fat and throw it into the fire. Two pairs of heads of sockeye-salmon are painted red: one pair is thrown into the fire, the other into the water.

Tᴇluwā'mᴇt, the Milky Way, is the place where the two parts of the sky meet. It is the road of the dead. Most of the constellations were made by Qäls, who transformed men and transferred them to the sky. The Pleiades, for instance, were children whom Qäls met when they were crying for their absent parents.

I heard only a few remarks referring to the dances of these tribes, which appear to have been similar to those of the Lku'ñgᴇn. The dancing season was called by the Kwakiutl word Mē'itla. It is a very curious fact that the raven was believed to give the dancers or the members of the secret societies their songs, as the raven, who plays an important part in the mythologies of the northern tribes, does not seem to be considered a powerful being by the tribes of Fraser River, excepting in this one connection. One group used to tear dogs. Another one called the Sk·ē'yip inflicted wounds upon themselves, drank the blood streaming from these wounds, and after a short time reappeared sound and well. When they were frightened by other dancers they vomited blood. Another group was called the Tᴇmᴇqā'n. Evidently these dances were quite analogous to the festivals of the secret societies of this region.

I add a few current beliefs: The grass over which a widow or a widower steps fades and withers. Before marrying again, the widow or widower must undergo a ceremonial cleansing, as else the second husband or wife would be subject to attacks of the ghost of the deceased.

If one takes a particle of decayed tissue from a corpse and puts it into the mouth of a sleeping person, the latter will 'dry up and die.'

Chiefs' children were carefully brought up. They were instructed in all arts. They were enjoined not to steal, and always to speak the truth. They were not allowed to eat until late in the evening, in order to make them industrious. Young men who returned from a successful hunting expedition were required to distribute their game among the whole tribe. Poor people did not train their children as carefully as chiefs and rich people.

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[1] See the sixth report of the Committee; also *Verh. der Ges. für Anthropologie zu Berlin*, 1891, p. 550.

The Structure and Function of the Mammalian Heart.—Report of the Committee, consisting of Professor E. A. SCHÄFER (*Chairman*), Mr. A. F. STANLEY KENT (*Secretary*), *and* Professor C. S. SHERRINGTON. (*Drawn up by the Secretary.*)

The research may be divided into three parts :—

1. Observations on the Structure of the Heart.
2. Experiments on the Relation between Structure and Function.
3. Experiments with Anæsthetics.

1. *Observations on the Structure of the Heart.*—These observations have been made principally on human hearts, and tend to show that the condition which I have described[1] in the hearts of animals lower in the scale persists even in man. That is to say, the auricles and ventricles are connected by strands of muscular tissue passing across the groove, though, as might be expected from my former observations, these strands are less marked in man than in the lower animals.

In man, as in all other animals examined, the muscular connection is more perfect in the young condition, and the younger the subject the more perfect the connection.

To go more into detail, the ring at the base of the auriculo-ventricular valves is composed of a dense mass of white fibrous tissue in which are scattered many connective-tissue corpuscles, and this mass becomes continuous with the connective tissue running between the muscular fibres of auricle and ventricle respectively.

The greatest development of connective tissue takes place at the bases of the valves, which are supported on specially thickened portions of the ring, and are largely composed of bundles of fibres running out from it.

Bundles of muscular tissue also occur in the valves, and these bundles are usually connected directly with the muscle forming the walls of the auricle. In actual shape and arrangement the fibrous tissue forming the ring differs in different situations.

At the posterior aspect of the left ventricle the auricular muscle is completely separated from that of the ventricle by a more or less pyramidal mass of connective tissue, the base of the pyramid being directed outwards and forming part of the external surface of the heart, the apex being directed inwards and becoming continuous with the base of the mitral valve. The auricular muscle runs downwards on the inner aspect of this mass of fibrous tissue, and ends as a thin sheet just above the base of the valve. The ventricular muscle ends as a much thicker mass just beneath the base of the valve.

An exhaustive examination has been made of the relations of muscle and connective tissue in this situation, but a description without figures would be tedious, and followed only with difficulty. Suffice it to say that in the human heart, as in the hearts of other animals, the auricles and ventricles are connected by muscular tissue, and their connection is the more perfect the younger the heart.

2 and 3. *Experiments on the Relation of Structure to Function and*

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[1] *Journal of Physiology*, XIV., 4 and 5.

Experiments with Anæsthetics.—It will, perhaps, be best to take these two sets of experiments together. Shortly summarised, they have been made with the object of determining how the above-described points of structure affect the working of the heart, and more especially what practical use can be made of the knowledge gained in these observations.

It is well known that in young animals it is exceedingly difficult to produce any effect by means of chloroform—in fact, in my experiments I have often found it almost impossible to anæsthetise animals only a few days old. Gradually, as age increases, they become less refractory, and at a few weeks old (in the case of kittens) chloroform produces the same effects as in the adult.

More than this, however, in the newly-born animal it is almost impossible, push the anæsthetic as you will, to produce stoppage of the heart, though this is one of the accidents most to be feared in administering chloroform to an adult animal. But even in the adult, if the thorax be opened and the heart examined immediately after death by chloroform poisoning, it will be found that, though the heart as a whole is quiescent, a portion of it, the right auricle, is still beating. In other words, it is not the initial stage of the beat which is absent; the quiescence of the heart is rather due to a failure in the transference of the beat already initiated from auricle to ventricle. This failure occurs only in the adult or nearly adult heart, and it has been shown that it is precisely in these adult or nearly adult hearts in which the connecting link between auricle and ventricle is reduced to a minimum. The failure of the heart's action, then, may be supposed to be due to the failure of a strand muscle of comparatively small sectional area to convey to the ventricle a wave of contraction started in the auricle.

It occurred to me, then, that it might be possible in cases of chloroform poisoning to so improve the conducting power of this strand of muscle as to enable the waves of contraction to once again pass over the junction and cause contractions of the ventricle.

My experiments upon this point are at present incomplete, but I have obtained results which lead me to hope that the research will not be entirely without practical results.

On recent Researches in the Infra-red Spectrum.

By S. P. Langley, *D.C.L., LL.D.*

[PLATES II.-IV.]

[Ordered by the General Committee to be printed *in extenso.*]

I presented to the Association in 1882 at Southampton an account of some researches made by means of the bolometer in the infra-red spectrum formed by a glass prism; but though these labours have continued with occasional intermission during the past twelve years, it is, for reasons which will be explained later, only within the past three years that any notable advance has been made, and only within the past twelvemonth that such a measure of success has been attained as justifies the present communication.

This is not the time to give any historical account of discovery in the infra-red spectrum, but all those interested in the subject know that the first investigator here was Sir William Herschel, whose observations consisted essentially in finding that there was something which the eye could not see in a region which he proposed to call the 'thermometric spectrum.' His distinguished son, Sir John, made a curious anticipation of later discovery, by indicating, though crudely, that this invisible heat was not uniformly distributed, and a similar conclusion was reached in an entirely different manner, through the thermopile, by the too-early-lost Melloni. So ignorant, in spite of these investigations, of those of the elder Draper, and of the elder Becquerel, were we till lately, that when, quite within my own recollection and that of most of you, Lamansky in 1871 published from his observations with the thermopile a crude little illustration showing three inequalities in the energy curve, universal attention was excited by it among those interested in the subject.

Among other minds, my own then received a stimulus which turned in this direction, and having, as it seemed to me, exhausted the capacities of the thermopile, I invented an instrument for continuing the research, which was afterwards called the bolometer, and with which in 1881, at an altitude of 13,000 feet upon Mount Whitney, I found spectral regions hitherto unreached, and whose existence had not been suspected.

I returned with a strong impression of the prospective importance of this discovery, and laboured at the Alleghany Observatory in improving all portions of the new method of research, especially of the bolometer and its adjuncts, with the twofold object of obtaining greater sensitiveness to heat, and greater precision in fixing the exact point in the spectrum where the change of heat originated. With the former object such a degree of sensitiveness was at that time reached, that the bolometer indicated a change of temperature of $\frac{1}{100000}$ of a degree Centigrade, and with the latter, such precision, that it was possible to fix the relative position of a line not merely with a possible error of a considerable fraction of a degree, such as Lamansky's determination is evidently subject to, but with a certainty that the error would be within a minute of arc. The range of the apparatus in wave-lengths was almost unlimited as compared with any other process, and both its sensitiveness and its possible precision seemed to be at that time notable as compared with previous methods, for a great advance was made on anything done before with the thermopile, when the presence of the well-known 'D' line of sodium was rendered sensible (though barely sensible) even as a *single* line by the change of temperature. This sensitiveness was also, as has been said, accompanied with the possibility of unusual precision. The results of this labour were laid before the British Association in the communication already alluded to, and which exhibited ten or twelve inflections of the curve in the portion till then almost unknown, which extends from a wave-length of 1^{μ} to a wave-length of nearly 3^{μ}, at which point the glass prism then used became wholly opaque to radiation. The positions of these inflections were fixed with a precision quite impossible to the thermopile, but this exactness was only obtained in practice by a process so slow as to be almost prohibitory; and with this apparatus I made in those earlier years such a number of observations as I hardly like to recall, so disproportionate did the labour inherent in this method seem to the final result.

The justification of this labour seemed to lie in the fact that it does not appear that photography has ever rendered anything much below a wave-length of 1^{μ}—anything at least which has been reproduced for publication in a way which gives confidence that we are in touch with the original:

The processes which involve the use of phosphorescent substances have given some indications of lines considerably below 1$^{\mu}$, but it is safe to state that the work which has just been referred to as communicated to this Association in 1882 presents almost the only indications which we have possessed, even up to the present time, about the lower infra-red solar spectrum.

Now the curve which was given, even in the later Alleghany observations, made with the rock-salt prism, contained but a dozen inflections below the wave-length of 1$^{\mu}$·5, and these inflections, with their correct prismatic and wave-length positions, represent, I think, most of our present knowledge in these regions, even to-day.

To understand the method by which there were attained, but only at this great cost of labour, results till then unreached, it may be repeated that the bolometer had been rendered more sensitive than the thermopile, but that it was capable of being pointed, and its position in the spectrum being measured only by a tedious process, which has been exclusively used till lately (but which that presently to be described advantageously replaces). Whichever process is used, when the bolometer thread touches a cold line in the spectrum (since what is black to the eye is cold to it), a larger current flows through the galvanometer, and the spot of light marking the needle's motion is deflected through a certain number of degrees.

From this point forward, the new process, whose results I am about to have the pleasure of bringing before you, differs widely from the old. In the old, two observers at least are engaged: one, who notes that reading of the micrometer or of the vernier, which fixes in angular measure the exact part of the spectral region whence (though nothing is visible) a thermo-electric disturbance has proceeded; and another, who simultaneously notes through how many divisions of the scale the spot of light from the galvanometer mirror is deflected by the same electric disturbance. The process may be compared to a groping in the dark, and it was only by these means that the considerable inflections of the energy curve much below the region about 1$^{\mu}$ were then fixed by the bolometer, by being gone over again and again with what seemed almost interminable repetition, and which did in fact call for over a thousand galvanometer readings to obtain the position and amount of each single inflection of the energy curve, with the degree of accuracy which was then obtained, and which was shown in the former memoir.

If it took two years to fix the position of twenty lines by this process, it would take two hundred years to fix two thousand, supposing they existed, and it became evident that if the bolometer continued to be the only means available, new and more effective methods of using it must be found.

New Methods.

About ten years ago a plan was first studied, which has ever since been maturing, by means of which this work could be carried on, not only with far greater rapidity, but with greater certainty, and by an automatic process. The idea in its original simplicity is very easily understood.

In the old process, just described, the deflection of a spot of light upon a scale was read by one observer, while another read simultaneously the position in the spectrum of the cold band, or line, which caused the thermo-electric disturbance.

Now, in imagination, let us take away both the observer at the circle and the one at the galvanometer, and in the latter case remove the scale also, and put in its stead a photographically sensitive plate. As the needle swings to the right or left the spot of light will trace upon the plate a black horizontal line whose length will show how far the needle moves and how great the heat is which originated the impulse. If this be all, when under an impulse originated by the movement of the spectrum over the bolometer thread the needle swings a second time, it will go over the same place; but if the plate have a uniform vertical movement, proportional to the horizontal movement of the spectrum, the combination of the two motions of the needle and the plate will write upon the latter a sinuous curve which will be, in theory at least, the same as the curve formerly deducible, only with such pains, from thousands of such galvanometer readings.

If we suppose that the movements of the invisible spectrum are controlled by clockwork, so that this spectrum is caused to move uniformly over the bolometer thread, and that these movements are, by accurate mechanism, rendered absolutely synchronous with those of the moving plate, it is clear that we shall be able to readily deduce from the photographic curve traced on the latter not merely the amount of the heat, but each particular position in the spectrum of the thread of the bolometer, which alone can correspond with any given inflection of the curve.

Thus simple is the theory, but no one had better occasion to know how difficult the practice would be than myself.

The researches by the old method and the early attempts to improve them were interrupted by my acceptance, in 1887, of a position which implies the administrative charge of different branches of the public scientific service, and of duties largely incompatible with original research. What time could be spared from these was, however, partly employed in elaborating the plan of investigation just referred to. An appropriation had been asked of Government for the establishment, on a modest scale, of an Astro-physical Observatory in Washington, whose first work should be the investigation of the whole infra-red solar spectrum, by some means which would open that great region to knowledge. It had been asked of Government, because it seemed that such knowledge, if attained, might teach us facts about the sun and the absorption of its rays by the terrestrial atmosphere, which, there was ground to hope, would ultimately lead to results of such importance as to justify this national aid.

These observations were resumed in 1890, on the new system, with the aid of the Smithsonian Institution which provided larger and more efficient apparatus, whose design embodied the results of nearly fifteen years' study of these subjects.

Pending the provision of a suitable observatory building, an inadequate and temporary one was erected in the Smithsonian Park in Washington, to shelter the apparatus presently to be mentioned, with which it was designed to commence work, while making provision for more permanent scientific quarters—which, I may add, are still lacking.

Apparatus.

The Foucault Siderostat—perhaps the most powerful instrument of the kind existing—was originally made by Sir Howard Grubb of Dublin, from my indications; but its dispositions have since been considerably modified. A beam from its twenty-inch mirror is conveyed through the slit of a horizontal collimating telescope having a rock-salt objective of nearly seventeen centimetres aperture, and of ten metres focal length, to the prism or grating. The prism is of rock salt, of corresponding dimensions, worked (by Brashear) with the precision of, and presenting all the external appearance of, one of flint glass. It is mounted on a massive spectro-bolometer (as the instrument which supports the prism or grating used in producing the spectrum is called). This instrument includes a large azimuth circle, over the centre of which the prism is placed; and it also carries the bolometer, which registers the spectral heat. The focal length of the image-forming lens, or mirror, is in this instrument much greater than in the first one used, and all parts of the apparatus are correspondingly increased in size and stability. The most important and novel feature is, however, the mechanical connection of the large azimuthal circle carrying the prism, with a distant photographic plate, susceptible of vertical motion, and which latter takes the place of the scale formerly in front of the remote galvanometer, both circle and plate being moved by the same clockwork, which is of such steadiness and precision as to make the two movements, as far as possible, perfectly synchronous.

To fix our ideas, let us suppose that the slow-moving azimuthal circle carrying the prism revolves through one minute of arc in one minute of time, in which case the spectrum will move horizontally across the vertical bolometer thread at a proportional rate. Now, if the same mechanism, which causes this circular motion of the prism and of the spectrum of one minute of arc in one minute of time, causes the photographic plate to move vertically before the galvanometer mirror at the rate of one centimetre of space in one minute of time—if there be no allowance to make for changes of temperature in the prism or for like corrections; if the mechanician has done his part in such perfection that everything works as it should—it obviously follows that, under such conditions, during every second of this minute a portion of the spectrum represented by the small quantity of one second of arc will have glided before the bolometer thread, and that during this same second the plate will have been lifted automatically through one-sixtieth of a centimetre of space.

This is one relationship of time and space in actual use here, though others may be established by the use of the change-wheels with which the apparatus is provided. The essential thing is that the plate shall show with great precision, and even on simple inspection, not only the inflections of the energy curve there written down, but the exact relative position in the distant spectrum which the bolometer thread occupied at the moment it caused the disturbance. In the case assumed, for instance, if we suppose that the record on the plate commences with the part of the spectrum whose angular value is 40°, then, since 1 millimetre corresponds to 6 seconds of arc, and so on, the existence of an inflection on the plate at 30 cm. $3\frac{7}{10}$ mm. would show that the disturbances originated at the point in the spectrum corresponding to an angular measure of $40° \; 30' \; 22''{\cdot}2$.

If the arm which carries the bolometer is n metres long, and if the thread of the bolometer is $\frac{1}{m}$ metres in diameter, the angular value of the bolometer thread is $\frac{1}{mn}$. At present the linear width of the bolometer thread is not very materially less than formerly, but it is used with a longer arm, and its virtual width is accordingly less. In present actual practice (to use round figures) the optical arm carrying the spectrum across the bolometer is 5 metres in length; and if the bolometer thread be $\frac{1}{20}$ of a millimetre in width, its angular value is evidently $\frac{1}{100000}$ of the radius of the circle in which it moves, or a little over two seconds of arc. When the heat is distributed over so large an area, that part of it which falls on a thread of given diameter is of course proportionately less, so that the greater precision of measurement demands a more sensitive construction of the bolometer, as well as a more accurate mechanism for pointing it. Improvements have accordingly been introduced in the construction of the bolometer, and a need for greater sensitiveness in the galvanometer has necessarily gone with them. This increased sensitiveness has caused increased liability in the latter to both systematic and accidental perturbations, and the elimination of these has been found the most formidable difficulty of the whole process. It has been effected largely by placing the whole apparatus under constant temperature conditions.

I take pleasure in acknowledging the advantage I have found in using both Mr. Boys's quartz threads, and the extremely small mirrors which he, I think, first advocated in connection with the well-known form of galvanometer due to Lord Kelvin. These and other collective improvements made in the bolometer and in the galvanometer have now made the former sensitive to changes of temperature in its strip which are demonstrably less than $\frac{1}{1000000}$ of a degree Centigrade.

These are the principal pieces of apparatus, though I should mention that a method has been found by which the very large salt prisms used can be preserved in perfect polish while exposed to all the usual casualties of observation. The actual prism in most frequent use was made from a block of salt exhibited at the World's Fair by the Russian Government, and presented to the Smithsonian Institution by its Commissioners. It is about 18 cm., or over 7 English inches, in height.

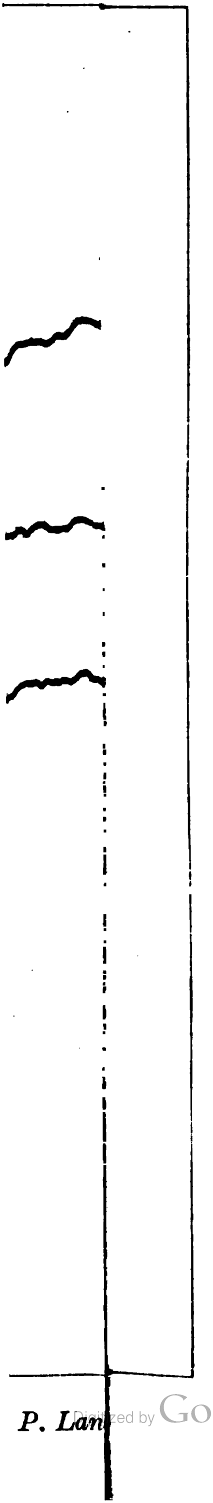
Before entering upon a description of the results obtained I desire permission to speak of the aid I have received from the gentlemen whose assistance I have been fortunate in securing. First to Dr. Hallock, then to Professor Hutchins, Mr. Hubbard, and Mr. C. T. Child, and lately to Mr. F. L. O. Wadsworth and Mr. R. C. Child, the imprint of the labours of the two latter gentlemen being upon almost all the details of the more recent work.

Results.

Let us recall that the infra-red spectrum from a rock-salt prism such as that used is extremely contracted as compared with one from flint glass, and still more contracted as compared with the wave-length scale. The portion of the spectrum presented by photography reaches a little below the band whose wave-length is about 1^{μ}, and this was asserted by one of the most eminent living authorities on the subject (Dr. John W. Draper) when the writer commenced this work, fifteen years ago, to be the absolute end of the heat spectrum. The writer has, however, since carried his investigations by direct measurement to five or six times this wave-length, and by indirect measurement much farther still, though what is now exhibited does not go beyond a wave-length of about 4^{μ}. The invisible heat spectrum of a 60° rock-salt prism through this great wave-length includes only somewhat less than 2° of arc, and the first of these degrees contains the greater proportion of the energy.

On referring to the illustrations exhibited to the Association in 1882, ven to later publications of results obtained by rock-salt prisms, though

g. 1).



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with the old method, it will be seen that there are shown in the latter publications about a dozen measured inflections of the energy curve below 1$^{\mu}$·5, and it may be remembered that this curve was obtained only by two years' assiduous labour.

We have now before us (fig. 1, Plate II.) three energy curves, obtained by the new method, each exhibiting the whole infra-red spectrum under examination, with about a hundred inflections. These curves are nearly, but not exactly, similar.

The three were obtained on the same day, each from an entirely independent observation, so that each has given in a fraction of a day many times the results previously obtained by two years of labour, and, as it will be later shown, has given these results with a notable gain of accuracy.

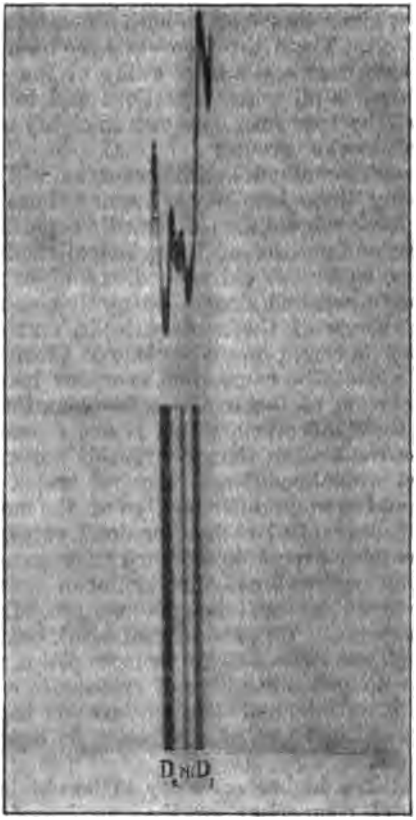
But this is not all. These three curves have been taken with a rapid movement of the clockwork and a brief swing of the galvanometer, so as intentionally to suppress all minor inflections and to introduce only the leading features of the spectrum, as shown in eighty or a hundred of the leading inflections (lines) or groups.

This new bolometric method has, however, as will be shown later, a capacity of resolving these into nearly twenty times that number, the minor inflections having been thus designedly suppressed here, to better show the character and position of the principal ones. All these energy spectra, by the new as by the old method, are, of course, subject to the slight changes due to invisible clouds constantly passing before the sun, which, with the change of the sun's altitude, and of the consequent lengthening path of its rays, prevent any one of them from being exactly like the other; while, at the same time, everyone here may satisfy himself, by direct inspection of the results before him, that there is scarcely any single one of their inflections which is not reproduced in the other two, in exactly the same place, though probably not exactly in the same degree; and when we take different spectral traces, made at different hours of the day, and even on different days of the month—traces which are absolutely independent of each other—and superpose them, experience shows that we may expect to see such an agreement as that in the three here chosen at random for illustration, or in the more detailed one, where the relative probable error is less than one second of arc. Three such traces only are here given (to prevent confusion), but if we follow these coincidences through not three, but ten or more plates, we may well judge (since there seems no possibility here of systematic error) that a result which all confirm is reliable, and that, on the other hand, a single inflection on one plate, which the other nine unite in repudiating, is due to some fortuitous cause.

But there is still a higher certainty to be obtained, by a method independent even of comparison or the exercise of judgment. It is founded on the well-known process of composite-photography, where, in photographing the successive members of an assemblage of persons, having similar general characteristics—as of race, character, or education, the individual disappears and the normal type alone remains. In order to apply this method to such results as ours, however, another step in the process must be introduced, and this is an interesting one, for the energy curve itself, however valuable, is a comparatively unfamiliar method of showing variations in the energy, which we are all alike used to seeing in the visible spectrum, given by linear representations, and not by a system of inflections.

In describing this new step which is to give us a *linear* spectrum, in addition to the original curve, it will be desirable to also give evidence of the statement now made, that the present method is capable of recording far minuter inflections than those shown in the curves exhibited (Plate II), which, as has just been stated, have been taken only for the purpose of illustrating such more important features as can be seen and verified by the audience, and especially for showing the agreement of independent observations. The evidence of the capacity of the apparatus to show this detail will best be illustrated by applying our purely thermometric method to some well-known lines in the visible spectrum, such as the familiar 'D' lines of sodium. I have already stated that ten years ago the bolometer was barely able to distinguish this as a *single* line. At the present time our little thermometer, as you see (fig. 2), now shows not only the two 'D's' as separate lines, but the nickel line between them. First we have the complex energy curve, where we see successively the inflections due to the motions of the galvanometer caused by the cold in D$_1$, then to the smaller chill from the nickel line (aided, perhaps, by that from some of the close atmospheric lines), then the chill from D$_2$.

FIG. 2.



Immediately below this curve is the more familiar linear representation of the same subject. Now this linear representation, it is most important to observe, has been obtained, not by drawing, but by the subsequent application to the curve of an automatic process, by means of which its indications are reproduced by photogravure, as separate lines; while, by the same automatic process, the most complex spectral curves can be rendered into their linear equivalents.

I have no space to enter here on a description of this process, further than to say it is effected by means of a systematically distorted image of the curve, obtained by a special combination of spherical and cylindric lenses. You will see, on minute inspection, that the inflections of the galvanometer curve have been slightly 'loaded,' to produce a more effective contrast of light and dark. Except for this, which can in no way affect the position of a line, but only its intensity, the whole process is as absolutely automatic as any photograph of the visible spectrum.

This thermograph of the 'D' lines has been chosen to indicate the grasp of this new thermometric method, by applying it to the test of an object in the visible spectrum with which every physicist is doubtless familiar. He may then be invited to recall that the distance between the 'D's' in a rock-salt sixty-degree prism is about eleven seconds of arc, and to observe that two lines, about half this distance apart, are here shown as sharply divided by this thermal method as, for instance, are the components of the double star α Geminorum by a 3-inch achromatic. Obviously, then, our method could indicate the existence of two lines, little, if any, more than one-quarter the distance between the 'D's.' Lines $3''$ or less apart can, then, evidently, be indicated by this method, even in its present state of development.

And now, returning to what has been said about the evidence obtainable as to the perfect coincidence of these inflections in different energy curves obtained at different times, and to the consequent evidence that each inflection so given is real, and not the product of an accidental variation in the curve, we may conceive that from any number of such independent curves any number of such linear representations of the spectra have been obtained; for example, that ten such linear representations of the whole spectrum as are here given of the 'D' lines only, have been so found from ten complete energy curves taken on as many different days. From these ten linear representations, by the well-known processes of composite photography, *one* final photograph of the spectrum is formed, and on this it is evident we may expect to find only what is permanent and not what is accidental, granting that a rare accident may have introduced an occasional abnormal deflection.

Now considering that the part of the infra-red solar spectrum of rock-salt under review extends through nearly two degrees, or 7,200 seconds, and that we have just seen by the illustration of the 'D' lines (fig. 2) that lines $3''$ apart can be thus indicated, we may see for ourselves that at any rate over 2,000 lines, if they exist, can be mapped. But these lines do exist, the whole of this new region being apparently as intimately filled by them as the visible spectrum by the Fraunhofer lines. In further evidence of this I now show a portion of the lower spectrum (fig. 3, Plate III.)[1] in the comparatively unknown part extending from $\lambda = 1^{\mu}\cdot 4$ to $\lambda = 2^{\mu}\cdot 2$, including the great band Ω shown as a single inflection in my first communication to this Association, but here resolved into thirty or more subordinate lines. This illustration includes a part of the new region discovered on Mount Whitney in 1881, and in the small portion here exhibited it may be seen that about 200 lines are discriminated.

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[1] This figure, exhibited here only in illustration, is not to be treated as a criterion of the final results to be attained by the composite process.

I am now trying to bring what may be called the first stage of the long labour, a portion of which is here described, to a close, this first stage consisting chiefly in the discovery of and mapping the relative positions of new spectral lines.

I will only refer to what it seems to me the second part of this work is likely to be, and to the different kind of interest which may not improbably belong to it, from that which belongs to this the first.

We are thus far in the position of early students of the visible spectrum, who simply drew the lines they saw without inquiring into their meaning. Nevertheless, to have discovered and mapped a great number of these lines is only a beginning, for their real value lies in their interpretation, and this is still chiefly to come. As to the possible importance of this interpretation, it is not enough to remind ourselves that three-quarters of the whole energy of the sun exists here and not in the upper spectrum. We must remember also that while, as a rule, in the upper and visible spectrum a great proportion of the lines are caused by absorption in the solar atmosphere, and a perhaps smaller portion by telluric absorption ; here, on the contrary, we are led by everything we already know to expect that the great telluric absorptions on which meteorological predictions and other immediately practical interests depend may be expected to be found, and it is on the comparison of these energy curves taken at different periods of the year and at different altitudes of the sun, that those who are engaged in the work see good cause to hope for important results in the future.

Before I conclude let me present a collective view of (fig. 4, Plate IV.) the field in which work has been going on in these later years at the Smithsonian Observatory on the same scale with the visible spectrum ; I say 'on the same scale,' meaning not on a wave-length scale which expands the invisible at the expense of the visible, and not on a prismatic scale alone which expands the visible at the expense of the invisible, nor even on such a logarithmic one as that proposed by Lord Rayleigh, but on a conventional scale, which I will ask you to tolerate, as it is simply meant to show the actual extent and importance of the region covered here, as compared with that known to Newton. In this illustration, with which I close my remarks, the mean dispersion throughout the invisible rock-salt spectrum, as far as 4^{μ} is taken as the standard, and both spectra are laid out on that common scale. On the left is the visible spectrum known to Newton : next this is the region known through photography, now extending a little beyond the band $\rho\sigma\tau$ which marks what, at the time these researches were commenced, was considered by the then most distinguished investigator in the infra-red, the end of the heat spectrum. Beyond, and on the right, is a part of the new regions of the spectrum developed by the bolometer, and of which charts may be shortly expected on the scale of which a specimen in detail has just been shown.

I cannot close this statement without expressing the gratification with which I have laid it before the same body that listened to that made on the same subject twelve years ago, or my sense of my good fortune in doing so before an audience in which I recognise many of the same eminent men who so kindly received that first presentation of these researches.

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On the Formation of Soap-bubbles by the Contact of Alkaline Oleates with Water. *By* Professor G. QUINCKE, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

SOME years ago I showed that soap-solution could be spread out on the common surface of oil and water or of oleic acid and water. The surface tension is diminished by this spreading more than 80 per cent. The spreading forms vortices in both liquids, and attracts all matter to the centre of spreading. If the soap-solution is formed by the oleic acid in contact with water containing potassium, sodium, or ammonia on the surface of a drop of oil, suspended in water of the same density, near the wall of the glass vessel or near viscous substances, the drop of oil is attracted by the wall or the viscous matter. The formation and the spreading out of soap-solution may be periodical and the movement periodical. If the period is very short the movement is apparently continuous. Oil-bubbles filled with water or small bodies covered with very thin films of oil are displaced in the same manner as oil spheres by the spreading of soap-solution.

I think that this new principle of movement will also explain a great many phenomena in organic nature, and I have tried also to explain by this new principle the spontaneous formation of emulsion or foam by the contact of oil (with oleic acid) and alkaline water, the foam-structure and the motion of the protoplasm in the cells of the plants.

Very thin films of oil are sufficient to show this motion by periodical spreading of the solution of very small quantities of soap, so thin and so small that they cannot be seen with the microscope or recognised in any other way.

Recently I have studied the phenomena by the contact of the oleates of potassium, sodium, and ammonia with water. The neutral oleates are dissolved by water, and form a viscous liquid. With more water an acid salt is formed and the alkali is dissolved in the water. These acid salts or acid soaps are not soluble in water, or only slightly soluble in water. By longer contact with water they are dissociated, and form again liquid oleic acid and neutral oleates or soap-solutions.

When small quantities of neutral oleates are placed in contact with water between the cover-glass and the slide, and are examined by a microscope with polarised light, they are found to be covered with thin films of oleic acid. This film dissolves oleate and water, and the diffusion of both substances will bring water to the soap inside the oil-film of oleic acid, and oleate to the water outside the oil-film. The volume of the soap inside the oil-film is increased, the soap-solution formed on the common surface of oil and water is spread out, and now the vortices, excited by the spreading, attract the matter, the soap, and the liquid. In this way are produced very curious forms called myeline by Virchow, who first observed them in putrefied brain. These myeline forms—crystals of soap (with water of crystallisation, covered with the thin oil-films and showing a smooth surface)—are doubly refractive.

The 'liquid crystals' observed by Professor Lehmann, of Karlsruhe, in fused benzoylcholesterine and fused azoxyanisol are also doubly refracting crystals, covered with a thin film of oily matter formed in the liquid by the fusion.

When more water diffuses through the oil-film to the soap inside there is formed a viscous liquid, a solution of the oleate in a jacket of oleic acid. The movement of the water and the periodical spreading of soap-solution will form long filaments or cylinders of viscous matter covered with an oil-film. The oil-film contracts and forms bubbles in the middle and the ends of the oil-filament. By the spreading of soap solution the bubbles wander along the oil cylinders with different velocities and in different directions. After some time the oil cylinders are deformed and become strings of beads of oleic acid and thin oil-films. The thin oil-films form foam or bubbles filled with water or weak solution of soap.

In the oil-film are distributed lenses or spheres of oil filled with strong or weak soap-solution. Some methylene-blue dissolved in the water is collected or stored up in the oleic acid, so that the coloured oil and the water may be very easily distinguished.

The spheres of oleic acid coloured with methylene-blue are arranged on the edges of the films of the bubbles or spherical films of the foam, and the appearance is similar to the appearance presented by the stars of the Milky Way. The formation of chains of stars, as observed by Professor Max Wolf, and the spiral nebula in Perseus in the excellent photographs of Dr. Roberts, are similar in appearance to the phenomena observed by me in these microscopical oil-films and bubbles.

Fifty years ago Plateau pointed to the analogy of the rotation of the sun and the planets with the rotation of oil-spheres suspended in a mixture of alcohol and water of the same density. Now we have a new analogy between the arrangement of matter of the universe by forces acting at very great or very small distances. From the standpoint of our modern physics, with the Newtonian law of gravitation and the law of action of molecular forces, these analogies may appear to be somewhat arbitrary. But we must be able to pass from definite distances to infinitely great or to infinitely small distances of the acting masses, and we can conceive that it may be possible that the difference between the law of gravitation and the law of the molecular forces may disappear, and that we may have the same law for small and great distances; so that the distribution of matter may be accounted for by the same forces, when the masses and the distances of the masses are increased in the same proportion, a million or a billion times.

The work of future generations will decide whether researches on the microscopical oil-foam or on the stars of the universe will give the solution of this problem.

On the Displacements of the Rotational Axis of the Earth. By Professor W. Förster, *Director of the Royal Observatory of Berlin.*

[Ordered by the General Committee to be printed *in extenso.*]

Displacements of the rotational axis of the earth with reference to fixed directions in space have been observed since the earliest ages of astronomical measurement; for such displacements, visible in wanderings of the pole of the apparent diurnal rotation of the celestial sphere among the constellations of fixed stars, exist in such enormous amplitudes, that in their main features they could be detected by the aid of very simple apparatus and observations.

The true law and explanation of these wanderings of the pole remained, nevertheless, a deep mystery till Copernicus lifted the veil by showing that they were only the celestial image of real displacements of the rotational axis of the earth in space, and until Newton came and, combining his discovery of universal gravitation with his deduction of the ellipsoidal figure of the earth, proved that these displacements are due to the actions of the moon and the sun on the earth.

The mathematicians of the eighteenth century completed this explanation by profound researches embracing the full theory of free rotation of a solid system of masses, under the action of various disturbing influences, not only those acting from outwards on the rotating body (as in the case of the sun's and the moon's attractions on the earth), but also those depending upon the condition or changes within the rotating system itself.

Among several interesting results, these investigations pointed out an essential difference between the development of the disturbed rotation in the first and in the second case.

Upon the supposition, corresponding to the real terrestrial conditions of the problem, namely, that all the disturbing influences are relatively small in comparison with the amount of energy represented by the primary rotation of the earth itself, the following distinctions were demonstrated.

Exterior disturbing influences will mainly produce displacements of the axis in space, and corresponding wanderings of the pole among the stars; whilst the simultaneous displacements of the axis in the earth itself, in consequence of the particular conditions of their evolution, remain insensible.

On the contrary, interior conditions and disturbing influences, as those contained in the configurations of the masses, or in changes of the distribution of the masses composing the rotating system, will mainly produce displacements of the rotational axis in the rotating body itself, whilst in this case the simultaneous displacements of this axis in space and the corresponding variations of the position of the pole among the stars remain insensible.

Very soon after these deductions had been made from theory, astronomers began to inquire if also effects of the latter type—that is to say, displacements of the rotational axis in the earth—really existed.

According to theory, such displacements ought even to exist when the distribution of the masses composing the earth is not in the slightest degree variable.

It is sufficient for producing such displacements that the position of the rotational axis of the earth is actually not in perfect coincidence with one of its principal axes of inertia, known as the principal axis.

The slightest deviation of the rotational axis from the principal axis has the consequence that the pole of the rotational axis begins and continues to describe a small circle around the pole of the principal axis.

The velocity of this movement depends upon the law of the figure and of the distribution of the masses composing the earth, and the best numerical data for this dependence had given the result that the displacement in question would probably have a period of nearly ten months.

Now all such displacements, possibly measurable with reference to fixed directions in the earth, and insensible with reference to fixed directions in space, could be found in the most favourable way by measuring as exactly and continuously as possible the distance of the pole from the zenith of the observer's station; in other words, by repeated determinations of geographical latitudes. But, notwithstanding very long and refined determinations of the geographical latitudes at some of the principal observatories, beginning shortly before the middle of the present century, only very uncertain and discordant traces of the phenomena in question were found.

The reason for this want of success is now very clear. Astronomers had limited their researches too narrowly to the last-mentioned type—namely, to the supposed regular ten-monthly periodical movement of the pole of the rotational axis around the pole of the principal axis. Too easily it had been admitted that all the existing variations of the distribution of terrestrial masses were far too small for altering sensibly the position of this principal axis itself.

It was Lord Kelvin, at the Glasgow meeting of the British Association (1876), who first drew the attention of the scientific world to the consideration of the great natural transports of masses of air and water, and of various masses by the water, going on continuously and periodically in the form of currents and circulations of different kinds, as well in the atmosphere as in oceans and rivers, and the effects of the enormous periodical deposits of snow and ice. He showed that these very considerable variations of the distribution of masses on the earth could not only produce sensible displacements of the principal axis of inertia, but that such displacements of this axis could have an amplifying effect on the total amount of displacements of the rotational axis.

For if the principal axis were itself not in a constant position, the theoretically required movement of the rotational axis around the principal axis would become a very complicated movement, differing entirely from the simple form which to that time had appeared in the researches of astronomers.

This epicyclic character of the movement of the pole of the rotational axis could considerably modify not only the length of the period, but also the whole geometrical character and amplitude of the curve, in such a way that in longer periods epochs of very small variations of latitude could alternate with epochs of considerably increased variations of latitude. Possibly, as a further consequence of this complication of the displacements of the two axes, and as a consequence of the still existing plastic state of certain parts of the earth, as well as by the damping effects of the fluid parts, even *progressive*—though very slow and unsteady progressive—displacements of the rotational axis in the earth could still result.

The field of this research was thus decisively cleared by Lord Kelvin; and finally, about four years ago, by the co-operation of some Observatories with the International Geodetic Union, clear evidence was obtained, and in the last three years, with the aid of an expedition sent by the International Union to Honolulu, decisive proofs of such displacements have been found. I consider it a special honour and pleasure to be enabled to submit some of the newest results of this international co-operation to a meeting of the same Association which, twenty years ago, had been witness of the almost prophetic assertions of one of its most illustrious members regarding the real conditions of this important phenomenon.

I have prepared a diagram showing these newest results. In this diagram is given a representation of the wanderings of the pole of the rotational axis of the earth on its surface during the last twenty months, from October 20, 1892, to May 1, 1894.

This sketch is founded on nearly 6,000 single determinations of latitude made in the Observatory of Kasan (Eastern Russia), Strassburg, Elsass (41° 21′ west of Kasan), and Bethlehem, Pennsylvania (124° 30′ west of Kasan). The observations are condensed in twenty monthly mean results, numbered from zero to 19. Every one of these resulting monthly positions of the pole indicated by the centres of the small circles is thus the mean result of about 300 single determinations.

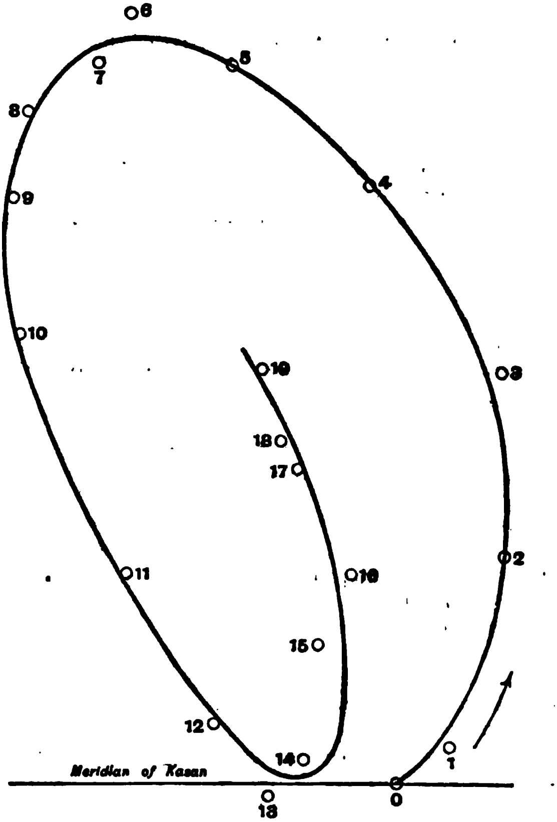


Figure showing movement of the North Pole of the rotational axis of the earth. Derived from observations made at Bethlehem, Strassburg, and Kasan :—

0=1892 Oct. 20.
1= „ Nov. 1.
2= „ Dec. 1.
3=1893 Jan. 1.
. . . . . .
. . . . . .

13=1893 Nov. 1.
14= „ Dec. 1.
15=1894 Jan. 1.
. . . . . .
19=1894 May 1.

The figure is drawn on the scale of two millimetres to one-hundredth of a second of arc, and the maximum amplitude of the curve is nearly fifty-hundredths, or half a second. The amplitude of these movements of the pole on the surface of the earth is between 40 and 50 feet.

The general character of the movement is quite in accordance with what has been mentioned concerning its complicated and somewhat spiral character. The sense of the motion is from west to east. The velocity is apparently very variable, and it seems as if we are now approaching an epoch in which the amplitude is considerably diminishing. It is also evident that such a character of movement can very easily produce slow progressive motions, and for this reason the whole phenomenon wants to be watched incessantly and very carefully.

The astronomers and geodetists who are now associated in the International Geodetic Union have invited geologists to associate with them in this common research. Such an international organisation will be also useful and almost indispensable for a great part of the work of astronomical observatories.

It is to be hoped that Great Britain will now participate in this International Union, embracing all other civilised nations. Such organisations, with their clear and reasonably limited aims, involve not only real economies and refinements of mental work, combined with diminutions of material expenses, but it is hoped that they will also have great importance as slowly growing foundations of human and terrestrial solidarity.

A Lecture-room Experiment to illustrate Fresnel's Diffraction Theory and Babinet's Principle. By Professor A. CORNU, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

THE diffraction fringes bordering the shadow of an object illumined by a point of light present us with one of the most striking phenomena in optics.

Dr. Thomas Young was the first to connect these fringes with the wave theory. According to him they were due to the interference of the direct wave with the wave tangentially reflected at the surface of the body screening the light.

Fresnel, following the way opened by Young, proved, however, by a very simple experiment, namely, by the identity of the fringes produced by the edge and by the back of a razor, that the reflected light has no appreciable influence on the production of these fringes. He proved that the phenomenon is exclusively due to the mutual interference of all the vibrations proceeding from the whole of the wave not intercepted by the object.

A mathematical investigation, and even a superficial analysis, shows that the resulting vibratory motion producing the fringes is equivalent to the vibration which would be caused by a permanent wave fixed at the edge of the body screening the light, provided that the acting part of this wave is reduced to a small breadth variable according to the obliquity of the rays. Consequently, everything happens as if the source of light were taken away, and the body were surrounded by a true luminous source forming a sort of border round its apparent contour. This result, proved for a single luminous point, is immediately extended to a circular source of light of any diameter considered as composed of points acting independently.

This optical equivalence is not only a symbolic or geometrical result, but a real physical fact, and the experiment, which I propose to show, gives the most striking evidence of the reality of this source of light.

To show the acting part of the wave surrounding the screening body three conditions are required:—

1. The plane of distinct vision must be made to coincide with the edge of the diffracting body.

2. The greatest portion of the diffracted rays must be preserved for producing the phenomenon.

3. The rays not employed in producing the phenomenon must be cut off.

It is not difficult to realise experimentally these three conditions, and the result obtained is extremely brilliant with sunlight. Though much less intense with the electric arc, it is nevertheless sufficiently distinct to be projected. With a feeble source of light, such as an oil-lamp, the phenomenon is still quite visible, but only by direct vision.

Let us take a luminous source of circular form (the disc of the sun or a circular hole in a diaphragm conveniently illuminated). Let the rays diverging from this source fall upon an achromatic lens (0·5 to 1 metre focal length) and produce at the conjugate focus a bright circular image of the source. Exactly at this focus let us place a black circular disc having precisely the same diameter as this image.

The eye placed behind this opaque disc will not see any point of the luminous source, because all the rays are cut off by the disc; it will perceive, however, a luminous line round the edge of the lens. This is in itself an illustration of the acting part of the Fresnel's wave, for the edge of the lens is really a screen which intercepts the incident wave. But the experiment becomes extremely striking if any object is put on the surface of the lens: this object appears on a dark field as if surrounded by a luminous line following even the smallest details of its edge. [In the experiment projected before the Section the object shown was a branch of fern.]

Moreover, each particle of the unavoidable dust lying on the lens produces a luminous point, and for this reason the field is never quite dark. Lycopodium thrown in front of the lens exaggerates this effect and produces a sort of luminous nebula.

The intensity of the bright bordering line depends upon the accuracy with which the circular screen masks the focal image of the source; if the diameter of the screen is too small the field becomes luminous, if it is too large the brilliancy of the line diminishes. If another shape be given to the screen the luminous line is interrupted normally to the directions in which the screen extends much outside the image of the source.

With the circular screen it is easy to observe the important particular case to which Babinet called attention, viz., that a very thin opaque line diffracts light exactly in the same manner as a transparent slit of the same form and size.

It suffices for this purpose to observe the shadows of successive wires, straight or curved, of decreasing diameters. The dark space lying between the two luminous edges in the case of a thick wire diminishes as the wire becomes finer, and vanishes when its apparent angle becomes sufficiently small; then the wire appears on the dark field like the incandescent filament of a glow-lamp.

The slits corresponding to the wires are made with lines of decreasing breadths traced on smoked glass. The appearances are exactly the same as before, a double bright line being produced by a broad slit, a single bright line by a narrow slit, so that a fine transparent slit and a fine opaque wire give exactly the same phenomenon. This is the simple and useful result called sometimes *Babinet's Principle*, and, in any case, the experiment just described gives immediately the means of verifying whether the conditions required for the correct application of this principle are sufficiently fulfilled.

All these results can be collected under a pretty form which illustrates one of the finest natural phenomena. It is well known that when the sun is hidden behind the top of a mountain, but near the crest, all objects in its neighbourhood are surrounded by luminous borders, and minute objects, branches, leaves of trees, flying birds, &c., appear on the sky as if incandescent.

To imitate this appearance it suffices to cut out in cardboard an irregular edge representing the crest of the mountain, and to border it with some blades of grass or moss representing trees. This object placed on the lens reproduces an image of this beautiful phenomenon, which seems to have been observed many centuries ago in deep valleys when the sun rises; for Shakespeare says (*Richard II.*, act iii. scene 2): 'He fires the proud tops of the eastern pines.'

The Connection between Chemical Combination and the Discharge of Electricity through Gases. *By* J. J. THOMSON, *Professor of Experimental Physics, Cambridge.*

[Ordered by the General Committee to be printed *in extenso.*]

THE intimate connection between chemical change and the passage of electricity through liquids has been universally recognised ever since Faraday discovered the laws of electrolysis which bear his name. These laws state that, whenever electricity passes through an electrolyte, chemical changes take place in the electrolyte, and that the quantity of electricity which passes through the electrolyte is connected in the most intimate and simple manner with the amount of chemical change which has taken place during its passage. For each unit of electricity which passes through the electrolyte a definite amount of chemical change takes place, and the chemical changes which take place when equal quantities of electricity pass through different electrolytes are chemically equivalent. But although chemists have largely availed themselves of the light thrown by electrolysis on chemical phenomena, the subject of the passage of electricity through gases does not seem to have attracted their attention. We have strong evidence, however, that the connection between the discharge of electricity through gases and chemical change is not less intimate than that between electrolysis and chemical change. Thus, for example, when the electric discharge passes through steam, the steam is decomposed, an excess of hydrogen appearing at one electrode and an excess of oxygen at the other; these excesses of hydrogen and oxygen are proportional to the quantity of electricity which has passed through the steam, and are equal to the amounts of hydrogen and oxygen which would be liberated if the same quantity of electricity passed through a water voltameter. We have here evidence for connecting chemical action with the discharge of electricity through gases of precisely the same kind as that which has connected it with electrolysis. Again, as I hope to show later in this paper, the passage of electricity through gases is influenced by various circumstances, such as the presence of very small quantities of water vapour, which exert so strange an effect upon chemical combination.

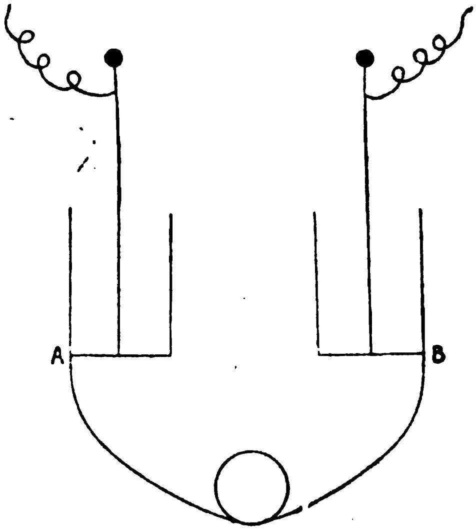
As for the opportunities for the study of chemical problems given by the phenomena of gaseous discharge, they seem to excel even those afforded by electrolysis, for the substances are in the gaseous state, the state in which the properties are the simplest and have been the most closely studied, while the visibility of the discharge facilitates the study of the electric phenomena, as it allows us to see, to some extent at least, what is going on.

The first point by which I shall illustrate the connection between chemical action and the discharge through gases is the influence exerted by water vapour on the potential difference required to initiate a spark through gas. The researches of Dixon, of Pringsheim, and of Baker, have established that water vapour exerts a remarkable influence on chemical combination. In several typical cases the presence of water seems indispensable for chemical action; two perfectly dry gases, even when they have as strong an affinity for each other as hydrogen and chlorine, seem utterly unable to combine with each other. The addition of a little water, however, is all that is necessary to cause combination to take place. As an analogue to this I shall now show some experiments which prove that it is extremely difficult to start a spark through a perfectly dried gas. When all traces of moisture are abstracted from the gas, the gas is able to withstand without sparking a potential difference many times more than that which would be sufficient to spark through it if it were slightly moist. The experiments suggest that, if it were possible to get a perfectly dry gas, then to spark through it would require so large a potential difference as to be far beyond any means of production at present at our command.

The experiments are of the following kind. The ends of a coil of wire are attached to A and B (fig. 1), the outside coatings of two Leyden jars, the insides of which are connected to the terminals of a Wimshurst electrical machine, or of an induction coil. When sparks pass between the terminals of the machine electric oscillations are started, and we have electric currents of very high frequency passing to and fro through the wires connecting the coatings of the jars. By using jars of suitable size it is easy to send through the coil electrical currents which reverse their direction several million times per second. This coil, with the alternating currents passing through it, may be compared to the primary of an induction coil, and it will induce currents in any neighbouring conductor. If we place inside the coil a bulb containing some gas at a very low pressure, the gas will be subject to electro-motive forces due to the electro-magnetic induction of the alternating currents in the coil; if these forces are very intense, they may be sufficient to cause a luminous discharge to pass through the gas. This discharge will take a ring shape, since the electro-motive force due to the alternating currents in the coil will act round rings parallel to the plane of the turns of the coil. I now place in the coil this bulb, which contains gas which has not been specially dried, and you see that the ring discharge flashes through the bulb whenever sparks pass between the terminals of the Wimshurst machine. I will now use this arrangement to show the effect of drying the gas, remarking in passing that the effect of moisture is not confined to any particular method of producing the electro-motive force, and is just as marked when the E.M.F. is steady as when it is alternating; in fact, I first noticed the effect when using a battery made up of a very large number of storage cells.

The apparatus consists of two equal bulbs, connected by a glass tube, which is open originally but afterwards fused up: one of the bulbs contains carefully prepared phosphorus pentoxide, the other is empty of all but gas. The two bulbs were exhausted by an air-pump until the pressure of the gas in them was very low. They were then sealed off from the pump, and the passage between the bulbs was fused up. In this way the two bulbs are filled with the same kind of gas at the same pressure; the gas in one bulb will, however, gradually become dry, while that in the other will remain in its original damp condition. Just after the opening between the bulbs was fused up, the discharge passed freely through either bulb when placed inside the coil. After the apparatus had stood for some days, long enough for the gas in the bulb containing the phosphorus pentoxide to become dry, the two bulbs showed a marked difference in their behaviour when placed inside the coil. The discharge, as you see, still passes freely in the damp bulb; but not the faintest trace of discharge can be detected inside the dry one, and even when the distance between the terminals of the Wimshurst machine is increased far beyond that necessary to produce a discharge in the damp bulb, the dry bulb still remains free from discharge. It is thus evident that, to start a discharge in the dry gas, a much larger electro-motive force is required than is necessary to produce the same effect in the damp gas; in other words, the presence of aqueous vapour facilitates to a great extent the passage of the discharge.

FIG. 1.



If, however, I produce a brush discharge in the dry bulb by bringing to the outside of the bulb a wire connected with the high potential pole of the Wimshurst machine, the ring discharge will start at once in the dry bulb, and after it has once been started an electro-motive force, very much smaller than that which it withstood previously without giving way, is sufficient to send the discharge through it. In fact, when once the discharge has been started through the dry gas it is almost as easy to send the consecutive discharges through the dry gas as through the damp. If the dry bulb is put away and left alone, it will, after some time, recover its original strength. It takes, however, a considerable time to do this, and it is very often several hours before the bulb is restored to its original condition. The effect of depriving the gas of aqueous vapour is thus to increase the difficulty of getting the first spark to pass through the gas. After once the spark has passed, there is very much less difference between the dry and the wet gas. If, instead of these alternating currents, we use the direct current from a large battery of cells, we can easily measure the change in the potential difference required for the first and consecutive sparks ; all we have to do is to connect the electrodes of a discharge tube with an electrostatic-voltmeter. For damp gases the change in the potential difference between the first and following sparks is not very great. For very dry gases, however, the potential difference required to start the first spark may be quite indefinitely large ; but for the second and following sparks it will be almost identical with that for the damp gas.

Another striking effect produced by aqueous vapour is the change it produces in a phosphorescent glow which some gases emit after an electric discharge has passed through them. When the discharge passes through oxygen it is followed by a greenish yellow glow diffused through the bulb. This glow is very bright and lasts for a considerable time. It gives a continuous spectrum crossed by a few bright lines. When the discharge passes through cyanogen it is succeeded by a white glow which is very persistent, lasting in some cases for fifteen or twenty minutes. All the gases in which I have observed this glow have the power of forming polymeric modifications. Aqueous vapour produces a very marked effect on this glow. If an oxygen bulb is sealed up with some phosphorus pentoxide, then for a short time after sealing off the gas will glow brightly after a discharge has passed, but as the gas gets drier the glow gets fainter, and after a few days is hardly visible. On the other hand, air, which only shows a very faint glow when moist, gives quite a bright glow when carefully dried. This glow is of the same character as that in damp oxygen.

The way in which the presence of water vapour facilitates the discharge and affects its appearance may be compared with its effect on chemical combination. Dixon, Pringsheim, and Baker have shown that certain typical combinations do not take place at all unless water vapour is present. If we take the view—which is, I think, proved by the phenomena accompanying electric discharges through gases—that the first discharge through a gas in its normal state is accompanied by the splitting up of some of the molecules of the gas, we can see why a cause which increases the facility with which the first discharge passes through the gas should also increase the tendency of the gas to enter into chemical combination. The forces holding together the atoms in a molecule are so great that if we were to take a single molecule of a gas by itself the electric field required to pull the atoms in the molecule asunder would far exceed in intensity any hitherto applied to a gas. For consider two atoms in a molecule each charged with the quantity of electricity which the electrolysis of liquids shows is carried by each atom of an electrolyte, and which from the results of experiments of the electrolysis of steam we may infer is carried by an atom of a gas. This charge, which we shall call e, is of the order 10^{-11} in electrostatic units. If r is the distance between the atoms in the molecule, the force on unit charge at one of the atoms due to the other is e/r^2. If we take r equal to 10^{-8}, this force is equal to 10^5. To pull the atoms apart would require a force comparable with this. As a force of 10^5 in C.G.S. units corresponds to thirty million volts per centimetre, we see that to separate the atoms in a molecule would require the application of an electric force far transcending in intensity any hitherto applied to a gas. A single molecule or a system of molecules free from each other's action would, therefore, not be split up by the fields which are found to produce discharge through gases. Such fields, however, might produce discharge if there existed in the gas complex molecules from which the charged atoms could be more easily detached than from isolated molecules. The formation of these aggregates or large molecules with but loose connection between the atoms would on this view be an essential preliminary to the passage of the discharge. The presence of a third substance, such as water, may facilitate the formation of these aggregates by supplying nuclei round which they may condense. Indeed, a direct proof of the electrical effect exerted by water on the surrounding gas is indicated by the electrification produced when drops of water fall on a plate.[1] The most direct explanation of this phenomenon is that when a drop of water is surrounded by gas there is a finite difference between the potential of the gas and that of the water; in other words, there is electrical separation at the surface of the drop resulting in the formation of a coating formed of two layers of electricity close together, one of these layers being positive, the other negative. If the gas surrounding the drop is oxygen, the inner layer is positive, the outer negative; while if the drop is surrounded by hydrogen, the inner layer is negative, the outer one positive. Thus in a system consisting of water and gas effects take place which result in an electrical separation which becomes apparent when the drop receives such a comparatively trifling disturbance as that produced by falling on a plate. Water is, with the single exception of mercury, the liquid where the electrification by drops attains the greatest dimensions. It is also the substance that, as far as our present knowledge extends, produces the greatest effect both on the electric discharge and on chemical combination. As the electrification is carried by atoms, and as these can be separated by the splashing of the drops on the plate, the electrification of drops furnishes independent evidence of the ability of water to put the surrounding gas into a condition in which some of the atoms are but loosely attached together. Although in this case the phenomenon is observed with liquid drops of a finite size which we cannot suppose to have any permanent existence in those cases where a trace of aqueous vapour produces such an effect on the passage of electricity and on chemical combination, yet, if we realise this action of drops, we shall, I think, get a clue to the explanation of the action of small quantities of aqueous vapour. For let us suppose that we have a drop of water in air with its double layer of electrification, and that this drop for some reason or another evaporates. Blake's experiments show that the steam from this drop is not electrified, so that if we proceed to the limit and suppose all the water to evaporate, the charged atoms constituting the double layer will still be left, and we shall have a number of oppositely charged atoms held together by very loose ties. These would easily be split up themselves by the electric field, or would form excellent nuclei for the formation of loosely attached systems of molecules suitable for conveying the electric discharge. A quantity of water vapour alternately condensing and evaporating would throw the surrounding gas into a state in which it could transmit the electric discharge. This would be the case even though the existence of the drops was so transitory that the water was to all appearance continually in the form of vapour. That some drops should be formed, having a very brief existence it is true, even when the pressure of the water vapour is far below that of saturation, is what we should expect on almost any dynamical theory of evaporation. The effect of the drops in promoting the existence of free atoms would of itself tend to increase the likelihood of their formation, as we know from the experiments of R. v. Helmholtz and Richarz that condensation is much facilitated by the presence of free ions.

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[1] Lenard, *Wied. Ann.*, 46, 584; J. J. Thomson, *Phil. Mag.*, 37, 341.

Thus, a small quantity of aqueous vapour, portions of which, occasionally condensed for an instant into drops, might put some of the gas into a condition approaching dissociation, inasmuch as in this condition the atoms could easily be detached from each other. We might expect that when in this state the gas might enter into chemical combinations much more freely than before this dissociation took place. The effect of a drop of water on a molecule consisting of a positively electrified atom combined with a negatively electrified one near the surface of the drop is worthy of consideration. Pure water, though not a conductor, has yet such a high specific inductive capacity that its electrostatic effect is much the same as if it were a conductor. Now if we have a molecule consisting of a positively electrified atom, A, with a charge $+e$ and a negatively electrified atom, B, with a charge $-e$, on or near the surface of a conducting sphere, the effect of the electrification induced on the sphere is the same as if we had at A′ a point on the same radius as A inside the sphere, and close to the surface a negative charge equal to $-e$, and at B′ a point inside the sphere close to the surface and on the same radius as B a positive charge equal to $+e$. Now, the negative charge at A′ will almost neutralise at B the force arising from the positive charge at A, while the effect of the charge at B′ on B is along the radius at B, and thus has no effect parallel to the surface of the sphere; there would thus be nothing to oppose the motion of B away from A, and similarly of A away from B, as long as this motion took place parallel to the surface of the sphere. Thus, for movements of this kind the molecule would be dissociated by the presence of the sphere; this dissociation of the gas would facilitate the production of the electrification over its surface, also its tendency to enter into chemical combination.

We have hitherto been considering the passage of electricity through the gas. If we proceed to study the passage of electricity from a gas to a metal, we shall find that it is also facilitated by the presence of a third substance. This effect was very well shown in an experiment which I had occasion to make on the discharge of electricity through mercury vapour. A bulb for the discharge was prepared by taking a large closed vessel filled with freshly distilled mercury; this was connected by a glass tube to the discharge bulb; one end of a capillary tube was fused to this bulb, the other end dipped under mercury. When the mercury in the large vessel was heated, the arrangement acted like a mercury distiller and pumped itself: to hasten matters, however, as much air as possible was taken out of the arrangement by an air-pump before beginning the distillation. The apparatus was kept distilling for a whole day, the discharge tube being surrounded by a furnace and kept so hot that the glass was just on the point of softening; at the end of the day the discharge tube was sealed off, enough mercury having been run into a reservoir connected with it to cover up the two electrodes by means of which the discharge enters and leaves the tube, and also to form a large pool at the bottom, under which was an electrode connected with the earth. The bulb was allowed to cool to the temperature of the room, and then a discharge was sent through it from a high-tension transformer. The discharge presented a peculiar appearance, passing as a narrow well-defined band of light between the two electrodes: it was started only after great difficulty. After the discharge stopped, the mercury vapour in the bulb was found to be positively electrified, and this electrification had great difficulty in getting out of the gas; for although the two mercury electrodes which had been used as terminals and the large pool of mercury at the bottom of the bulb were connected with the earth, there was such electrification left in the bulb fifteen minutes after the discharge had ceased, that when the bulb was disconnected from the earth and connected with a quadrant electrometer, the spot of light reflected from the mirror was driven right off the scale. When the discharge passed through mercury vapour from which other gases had not been driven with so much care, there was a residual positive electrification, but this disappeared so quickly after the discharge stopped, that after a minute it was too slight to affect appreciably the electrometer. This experiment shows that the communication of electricity from a gas to a metal, in this case from mercury vapour to liquid mercury, is very much facilitated by the presence of a third substance.

The well-known chemical phenomenon that many chemical reactions do not take place unless the temperature exceeds a certain value, is also paralleled by one in the discharge of electricity through gases. Certain gases, such as iodine, when strongly heated, allow electricity to pass through them with considerable facility; this, however, is only possible when the electrodes which carry the current into the gas are also at a high temperature. If we dip a piece of cold platinum foil between the electrodes when the current is passing through the hot gas, the current is immediately stopped apparently to as great an extent as if a piece of mica or other non-conducting substance had been inserted between the electrodes; as soon, however, as the piece of platinum foil gets to a dull red heat the current between the electrodes recommences, and the platinum now offers but little obstacle to the passage of the current.

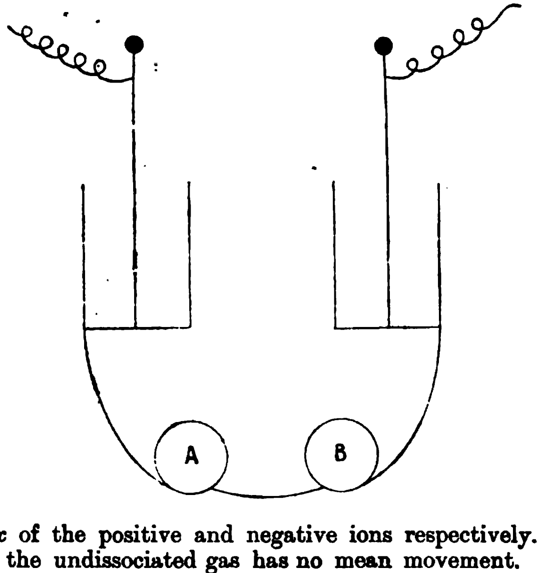
The electro-motive force required to liberate the ions from an electrolyte is connected in a very intimate way with the amount of work required to effect the chemical change which occurs when one unit of electricity passes through the electrolyte. Similarly, we may expect from the study of the potential difference required to send an electric discharge through a gas, to derive information about the work required to effect the chemical changes which go on when the discharge passes through the gas; as these changes seem often to consist in the splitting up of molecules into atoms, the study of the potential difference might be expected to throw light on the amount of work required to split the molecules of a gas up into atoms. Systematic measurements of the potential difference required to produce discharge have been made by several observers; they all, however, show one feature, which, until it is investigated, makes the deduction of conclusions as to the work required to effect the changes in the gas impossible. This feature is well illustrated in an experiment described by Hittorf, its discoverer. Hittorf measured the fall of potential in a vacuum tube, not merely between the electrodes but also along the whole length of tube, and found the very remarkable and interesting result that by far the greater part of the total fall in potential occurred close to the cathode. Thus in one of his experiments on hydrogen at a pressure of about $\frac{1}{100}$th of a millimetre of mercury he found that, of the total fall in potential, about $\frac{5}{6}$ occurred close to the cathode, the potential gradient in the rest of the tube only amounting to two or three volts per centimetre. The question immediately suggests itself whether, if we got rid of the electrodes altogether, we should reduce the potential difference to one-sixth or so of the value required when electrodes are used. I have here an experiment which is intended to settle this point; the apparatus consists of two bulbs connected together by an open tube, so that the bulbs are always filled with the same kind of gas at the same pressure. One bulb is without electrodes; the other, whose diameter is approximately equal to the circumference of the first, is provided with electrodes which are placed at the opposite ends of a diameter; these electrodes are connected with a wire which makes one turn round the coil which connects the outsides of the two Leyden jars (fig. 1); the bulb without electrodes is placed inside this coil; the total electro-motive force acting round the bulb without electrodes is thus approximately the same as that acting between the electrodes of the other bulb. Setting the Wimshurst machine in action, and gradually increasing the length of the spark until a spark passes, it is found that the discharge begins to appear at about the same time in each of the bulbs, showing that the total electro-motive force required to produce discharge is not very different in the two cases, and that the potential difference required to start a discharge through a given length of gas is not very greatly increased by the presence of electrodes. We may, therefore, conclude that the potential differences measured in the tube with electrodes are primarily connected with work required to split up the gas through which the discharge passes.

RESISTANCE OF RAREFIED GASES.

Rarefied gases are exceedingly good conductors of electricity when they are acted upon by electro-motive forces sufficiently intense to produce discharges. This is clearly shown by the following experiment. A and B (fig. 2) are two coils in series placed in circuit with the outer coatings of two Leyden jars. In coil A an exhausted bulb is placed; this bulb serves as a kind of galvanometer, the brightness of the ring in it giving an indication of the current passing through the coil A. The substance whose resistance is to be tested is placed in a bulb inside the other coil; the currents induced in this bulb will, by their inductive action, exert on the primary coil an electro-motive force in the opposite direction to the current in the coil; this will tend to stop the current, and we shall detect its effect by the diminution in brightness of the discharge in the bulb inside A. The extent of this diminution will give us a clue to the magnitude of the currents induced in the bulb B (fig. 2). I place inside the coil B a bulb containing gas at a low pressure. You notice that the discharge in A is quite extinguished. I now replace this bulb by one of the same size filled with sulphuric acid and water in the proportions for which they conduct electricity best. You observe that the sulphuric acid in B does not diminish the brilliancy of the discharge in A to anything like the extent the exhausted gas did; thus the currents passing through the gas are larger than those through the acid. If we compare the number of molecules of the gas with the number of molecules of sulphuric acid in the same volume, we find that the 'molecular conductivity' of the gas must be many million times that of the sulphuric acid (*see* J. J. Thomson, 'Recent Researches on Electricity and Magnetism,' p. 101). A calculation of the intensity of the current through the gas shows that some hundreds of amperes must be passing through a square centimetre of the gas, a greater current than is allowed by the Board of Trade rules to pass through the best conducting electric light leads.

The presence of a very small number of charged ions in a gas will impart to it a conductivity large enough to be detected by the method just described. As this method of detecting the existence of free ions may perhaps be of some service to Chemistry, it may be worth while to calculate from the principles of the Kinetic Theory of Gases the conductivity of a mixture of free ions and undissociated gas. For the sake of simplicity I will take the case when the ions form but a small fraction of the undissociated gas. Let e be the charge of electricity on the positive atom, m_1 the mass of this ion, $-e$ the charge on a negative ion, m_2 its mass, N the number of positive or of negative ions per unit volume, X the electric intensity parallel to the axis of x, u_1, u_2 the mean translatory velocity parallel to the axis of x of the positive and negative ions respectively. We shall suppose that the undissociated gas has no mean movement. Thus (Art. Diffusion, 'Encyclopædia Britannica,' or Maxwell's 'Collected Papers,' vol. ii. p. 629) we have, if ρ is the density of the undissociated gas,

FIG. 2.



$$\frac{du_1}{dt}+G_2\rho u_1+G_3Nm_2(u_1+u_2)-\frac{1}{Nm_1}\frac{dp_1}{dx}=\frac{Xe}{m}$$

where G_2, G_3 are constants depending on the size of the molecules and the temperature, p_1 is the pressure due to the positive ions.

If ρ is large compared with Nm_2, and if the state of the gas keeps uniform as we move parallel to the axis of x, this equation reduces to

$$\frac{du_1}{dt}+G_2\rho u_1=\frac{Xe}{m}$$

We shall first investigate the case when the electric intensity is constant; then when things are in a steady state du_1/dt vanishes, and we have

$$u_1=\frac{Xe}{m}\frac{1}{G_2\rho}$$

Now, if D_{12} is the coefficient of interdiffusion between the positive ions and the undissociated gas, then (Maxwell, *l.c.*, p. 631)

$$D_{12}=\frac{k\,k_1}{G_2p}$$

When p is the total pressure due to the ions and undissociated gas, k and k_1 are respectively the quotients of the pressure by the density for the undissociated gas and the positive ions. Now, since the ions form but a small part of the gas, the total pressure is practically equal to the pressure of the undissociated gas; hence we may put $p=k\rho$, so that

$$D_{12}=\frac{k_1}{G_2\rho}$$

and therefore

$$u_1=\frac{Xe}{m}\frac{D_{12}}{k_1}$$

Let us take the case of hydrogen ions, for which $e/mk_1=10^{-6}$ approximately. We do not know the coefficient of interdiffusion between hydrogen atoms and molecules; it will, however, be greater than that between oxygen and hydrogen, which was found by Loschmidt to be equal at atmospheric pressure to ·72. Hence, if in the equation for u we put $D_{12}=·7$, we shall get a value of u less than the true one. Substituting this value for D_{12}, we find

$$u_1=7\times10^{-7}X$$

If the electric intensity is a volt per centimetre, $X=10^8$. In this case $u_1=70$; hence for each volt per centimetre we get a velocity of hydrogen ions equal to 70 cm/sec. With the same electrical intensity the velocity will be inversely proportional to the pressure of the undissociated gas, so that when the pressure of this is $\frac{1}{1000}$ of the atmospheric pressure the velocity of hydrogen ions moving through it will be 70,000 cm/sec.

The current carried by the positive ions is

$$Neu_1$$

or at atmospheric pressure

$$7\times10^{-7}NeX$$

Since $e/m_1=10^4$ for hydrogen, we may put for the positive current

$$7\times10^{-3}Nm_1X$$

To get an idea of the magnitude of the resistance, let us assume that the current carried by the negative ions is equal to that carried by the positive. Thus, if q be the current, we have

$$q = 1\cdot4 \times 10^{-2} \mathrm{N} m_1 \mathrm{X}$$

Thus the specific resistance of the gas is

$$\frac{10^2}{1\cdot4 \times \mathrm{N} m_1}$$

Suppose that the hydrogen ions gave rise to a pressure of x atmospheres, then

$$\mathrm{N} m_1 = x \times 10^{-4} \text{ approximately,}$$

so that the specific resistance is

$$10^6/1\cdot4 \times x$$

Now, from experiments with electrolytes we find that we can easily detect by this method the conductivity of substances whose specific resistance is 10^{10}; hence we could detect the conductivity of the gas even though x were as small as 1/7000; that is, we could easily detect the presence of free ions though they only amount to one part in 7000 of the total gas. It is important to notice that, inasmuch as the conductivity varies inversely as the pressure of the undissociated gas, we should be able to detect the existence of the same percentage of free ions at all pressures.

Let us now consider the case when the electric intensity is variable. Suppose that it is proportional to $\cos pt$, say $\mathrm{X} = \mathrm{X}_0 \cos pt$; then we have

$$\frac{du_1}{dt} + \mathrm{G}_2 \rho u_1 = \mathrm{X}_0 \cos pt$$

or

$$u_1 = \frac{\mathrm{X}_0 \cos (pt - \epsilon)}{\sqrt{p^2 + \mathrm{G}_2{}^2 \rho^2}}$$

when

$$\tan \epsilon = \frac{p}{\mathrm{G}_2 \rho}$$

When the alterations in the electric intensity are so slow that p is small compared with $\mathrm{G}_2\rho$, the solution is practically of the same form as when the electric intensity is steady. But when the oscillations are so rapid that p is large compared with $\mathrm{G}_2\rho$, then approximately

$$u_1 = \frac{\mathrm{X}_0}{p} \sin pt$$

and the maximum velocity is independent of the pressure. In this case the direction of the electric intensity gets reversed many times in the interval between two collisions of the ion; thus the ions, when they have acquired a high velocity under the electric intensity, do not, as in the case when the electric intensity is steady, lose their energy by impact against other molecules, and so raise the temperature of the surrounding gas; when p is very large, the force is reversed before the ions collide, and the velocity of the ion gets reduced by the action of the electric force. There is in this case very little heat-production; the effect of the free ions is rather to alter the self-induction of the circuit than its resistance. Thus, if a light wave were passing through a medium with a small number of free ions, the effect of these ions would be rather to affect the velocity of propagation than to produce any great absorption. In the case of hydrogen at atmospheric pressures we have seen that $G_2\rho$ is of the order 10^{10}; in this case p would have to be larger than 10^{10} to make the effects depending on du_1/dt large compared with those depending on $G_2\rho u_1$. We could not by discharging Leyden jars get electrical vibrations of this rapidity, but at the pressure of $\frac{1}{10000}$ of an atmosphere $G_2\rho$ would only be of the order 10^6, and we could easily get electrical vibrations sufficiently rapid to make p large compared with this quantity, and thus to make the effects depend chiefly upon the term du_1/dt, that is, upon the inertia of the ions.

The preceding experiments are, I think, sufficient to show the close analogies existing between the phenomena of chemical combination and of the electric discharge, and give hopes that the study of the passage of electricity through gases may be the means of throwing light on the mechanism of chemical combination. The work of chemists and physicists may be compared to that of two sets of engineers boring a tunnel from opposite ends—they have not met yet, but they have got so near together that they can hear the sounds of each other's works and appreciate the importance of each other's advances.

On the Electrification of Molecules and Chemical Change.

By H. BRERETON BAKER.

[Ordered by the General Committee to be printed *in extenso*.]

MORE than twenty years ago a striking fact was discovered by Dr. Wanklyn, that dried sodium could be melted in dried chlorine without the production of the bright flame usual under the circumstances. The action of chlorine on other metals in absence of moisture was investigated by Dr. Cowper in 1876. He showed that in many cases the same result was obtained as that of Dr. Wanklyn in the case of sodium. About this time Professor Dixon, who was working on the rate of chemical change in a mixture of carbon monoxide, hydrogen, and oxygen, was led to suspect the great influence of the presence of moisture on the combustion of the former gas, and he succeeded, by drying a mixture of carbon monoxide and oxygen as completely as possible, in passing a stream of electric sparks in the mixture without any explosion taking place. It was this experiment which first led to the great interest taken by chemists in the influence of moisture on chemical action. Many chemists have investigated different chemical actions, and a large number of changes have been shown to be dependent on the presence of moisture. A list of them will be found in a paper on this subject in the 'Chemical Society's Journal' of July last. It seemed at one time to a chemist who was studying these actions, that no chemical action could take place without the presence of moisture. As action after action was investigated, and as new methods of purification were introduced, further additions could be made to the list. I have recently been engaged in studying several decompositions, however, and I believe that although, in some cases, no breaking up of the molecules takes place, as in the very interesting case of the action of heat on dried ammonium chloride, in which no dissociation occurs, yet in some cases action does take place. Potassium chlorate and silver oxide do decompose, and give not atomic but molecular oxygen. Carbon bisulphide burns in dried oxygen, although the elements of which it is composed do not. Oxygen forms ozone under the influence of the electric discharge as rapidly when dry as when moisture is present. It may be that the substances have not been sufficiently purified, but I believe it may be due to another cause. In many of these cases in which water-vapour appears to play no part, we are dealing not with molecules but with atoms. If an atom of oxygen will not unite with another atom of oxygen, then by the decomposition of dried potassium chlorate we should perhaps get a gas composed partly of atoms and partly of molecules, and by the decomposition of silver oxide, if its molecular formula is Ag_2O, the gas evolved might be composed only of atoms. In these cases, however, molecules of oxygen only are obtained. It may be, therefore, that, whatever be the state of dryness of the substance, atoms will always combine. Similarly with regard to the combustion of carbon bisulphide, though I used all possible care in its purification, yet it always burnt in dried oxygen. It was noticed, however, that the decomposition point of carbon bisulphide, when heated in a neutral gas like nitrogen, was a little below the point of ignition when heated in oxygen. Therefore, in the latter case, I was dealing not with carbon bisulphide and oxygen but with carbon bisulphide in a decomposing state, carbon and sulphur being set free not in their ordinary state but in a condition in which they would combine with dried oxygen. This fact is most easily explained by supposing that when carbon bisulphide is heated it splits up into atoms of carbon and sulphur, and that these then combine with oxygen in absence of moisture.

With regard to the explanation of the effect of moisture on chemical actions in general, several hypotheses have been suggested. The first, that of Professor Dixon, is that the water molecules present undergo an actual decomposition. In the combustion of carbon monoxide, for instance, the gas takes up oxygen from the water, liberating hydrogen, which then combines with the free oxygen, re-forming water. I venture to think that this hypothesis, although I believe it explains all the known facts, is open to one or two objections. For instance, if we accept Berthelot's law of maximum work, there seems to be no reason why water should be decomposed by red-hot carbon rather than oxygen molecules, since the direct action on the oxygen liberates a far greater amount of energy. Dr. Traube has suggested that the explanation is dependent on the oxidation of water rather than on its reduction; that hydrogen peroxide is first formed by direct union of water-vapour with oxygen, the peroxide again being reduced to water, giving up its extra atom of oxygen to the combustible. This hypothesis seems to be inadequate in many respects, since many actions in which water plays an important part, *e.g.*, the action of sodium on chlorine, or the combination of ammonia and hydrogen chloride, free oxygen is not present, and, therefore, hydrogen peroxide could not be formed.

Mr. Harcourt first suggested, in 1886, that the explanation of the action was to be sought from a physical, rather than from a chemical, point of view. Dr. Armstrong proposed in the same year a hypothesis, which he calls that of 'reversed electrolysis,' which supposes that no chemical action can take place without the presence of a third body, which must be an electrolyte. With regard to this theory I hope to be able to say more later. I am engaged upon an investigation whose object is to find out what substances can replace water in chemical action, and it may be found to be the case that all such substances are electrolytes.

I have been engaged during the last two years in an effort to investigate the question whether the union of elements and compounds was in any way connected with electrical discharge. The facts of electrolysis point strongly in this direction. I gave up at once the idea of directly investigating the question whether molecules of gases in cóntact were electrically charged, but in an indirect way I have obtained some evidence on the question. Taking a tube divided in the middle by a tap, and filling it with a mixture of dried ammonia and hydrogen chloride gases in equal proportions, I introduced at the two ends platinum plates which were oppositely charged from the terminal of a Wimshurst machine. After half an hour the tap was closed, and the gases in the two parts of the tube were drawn through a solution of litmus. On admitting moisture white fumes of ammonium chloride were produced, but there was found to be residual gas in both halves of the tube. The gas from the part which had contained the negatively charged plate turned litmus blue, and the gas from the other part reddened the litmus. The experiment was often repeated, and the result was the same. The separation was never very great, but the evidence of some separation seemed conclusive. With other gases there was also evidence of separation. With air dried by sulphuric acid there was found to be 1·8 per cent. more oxygen in the part containing the positive plate than there was in that containing the negative plate. Using a mixture of hydrogen and oxygen dried by phosphorus pentoxide, analysis showed an excess of 2·3 per cent. of oxygen in the part of the tube containing the positively charged plate.

It is possible, therefore, that the molecules of gases which may under certain circumstances combine together, may have an electrical charge. I hope to extend these observations to the case of other gases, and to find out, if possible, whether the charge on the molecules, if it exists, is theirs intrinsically, or if it only exists when molecules of a different nature are in contact with each other.

With the object of finding out if electric discharge bears any analogy to the process of chemical combination, I undertook some experiments a year ago to see if electric discharge in air was affected by drying the air as completely as possible. It was found that sparks from a Ruhmkorff's coil, when the discharge was very feeble, would leap across a space of moist air, but that none would pass in the dried air though the sparking distance was very much less. If, however, a strong discharge was used, sparks were obtained in the dried air, and, more than this, the feeble discharge would then easily pass in the dried air. These results entirely agree with those published by Professor J. J. Thomson.[1]

I am inclined to think, however, that there may be another interpretation of the latter part of the phenomenon besides that offered by Professor Thomson. It may be that the strong discharge splits the molecules into atoms, and that these can then carry on the feeble discharge. If this is proved to be true, it will serve as yet another point of analogy between chemical combination and electric discharge, for, as I have tried to show above, chemical combination does take place between atoms, whatever the state of dryness of their environment.

With regard to this analogy there may be found some evidence in the study of the action of actinic light on chemical combination and electric discharge. We find that when a mixture of chlorine and hydrogen gases is exposed to light, combination takes place only after a certain interval, and that the interval is not shortened by exposing the gases separately to the action of light. If the interval is spent in breaking up molecules into atoms we should expect that there would be an increase in volume. This increase in volume has been observed by Pringsheim with the mixed gases, though he ascribes it to another cause. I have undertaken some experiments with unmixed chlorine, and I found that in this case there is absolutely no increase in volume.

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[1] *Phil. Mag.*, October 1893.

Now with regard to the analogy of chemical action and electric discharge we find that light, and light of the same kind as that which brings about chemical action, has a remarkable influence on the passage of the electric discharge. This phenomenon was first noticed by the late Dr. Hertz, who found that when the negative pole of a spark gap was illuminated by an actinic light a discharge would pass which would not pass if the spark gap were unilluminated. It may be that the action of light is to split up molecules into atoms, and that the ready passage of the discharge is thus explainable. However this may be, I think that the analogy of the phenomena of electric discharge and chemical combination may be of importance. I have attempted to point out the analogy which exists when we work with substances which are in an exceptional state of dryness. Whether the analogy holds for other influences which affect chemical combination, and whether the analogies which I have indicated are only superficial and not real, can only be decided by a long series of experiments to which I hope to devote myself.

Report on Planimeters. *By* Professor O. HENRICI, *F.R.S.*

[Ordered by the General Committee to be printed *in extenso.*]

SEVERAL classifications of planimeters have been used by different writers, and different names have been used to distinguish them.

Mr. Boys distinguishes three types, which he calls Radius Machines, Sine or Cosine Machines, and Tangent Machines.

Professor Hele-Shaw has two classes only, according as the recording apparatus does or does not show slipping.

A more fundamental classification seems to be got on considering first of all the geometrical generation of the area by the motion of a line. This gives us three types: the first follows the generation of an area, as in the Integral Calculus, by rectangular co-ordinates; the second by polar co-ordinates; whilst the third is based on purely geometrical considerations due to Amsler.

In the following Report the classification adopted is:—

Type I. Orthogonal planimeters.
" II. Polar co-ordinate planimeters.
" III. Planimeters of the Amsler type.

Instruments of either type may have a recording or integrating apparatus with or without slipping, and this would give rise to subdivisions, which, however, it is not necessary to elaborate here.

This Report covers only a comparatively small part of the subject of integrators; it deals only with planimeters proper. Integrators for such purposes as the continuous registration of work done, integraphs and instruments for the integration of differential equations, harmonic analysers, &c., will not be considered. As it is in these more complicated instruments that the injurious effect of slipping is chiefly noticeable, a description of the various integrating apparatus will not be given. For the same reason the work of Maxwell, Lord Kelvin, Boys, Abdank-Abakanowicz, and Hele-Shaw will remain practically unnoticed.

With regard to the integrating apparatus in particular, there is the well-known paper on 'Mechanical Integrators,' by Professor Hele-Shaw, in the 'Proceedings' of the Institute of Civil Engineers for 1885, in which, besides, many descriptions with figures are given of instruments here treated of.

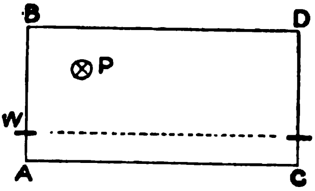
In this Report there is first given the geometrical theory of generating areas, together with simple descriptions of planimeters based on it. Then follows a historical sketch up to the invention of Amsler's planimeter. Next, this instrument is considered, its errors are discussed, together with those more modern planimeters which have been constructed with a view to avoid these errors. Lastly, some planimeters are described which have recently been introduced.

The object of a planimeter is to measure an area; it has, therefore, to solve a geometrical problem by mechanical means.

To give at once an idea how this is possible, consider a very simple case.

If a line AB (fig. 1) of finite length l moves parallel to itself to CD, where AB is perpendicular to AC, then it will sweep over the area of a rectangle which will have the value lw if $w=AC$. Let the line be replaced by a material rod QT, and let a wheel W be mounted on it. On placing this apparatus on the paper above the line AB, the wheel resting on the paper, and moving this rod along to CD, it will describe the same area. At the same time the wheel will turn and the arc of its circumference, which comes in contact with the paper, will have the length w. If the circumference is graduated and a fixed index is provided, say, at the highest point, the length of this arc can at once be read off.

Fig. 1.



This arc, as read off at the index, may be called conveniently the 'roll' of the wheel (Macfarlane Gray).

This instrument may be considered as a simple planimeter, which, however, measures only the areas of rectangles with fixed altitude, and is, therefore, practically of no use. Nevertheless it will serve to elucidate a great many properties common to nearly all planimeters.

First we have a geometrical generation of an area by aid of a moving line, and secondly the 'recording apparatus' represented by the wheel, with its graduation and index. It is advisable always to keep these two ideas quite separate. The one is *geometrical*, the other *kinematic*. The former of these will first of all engage our attention.

Geometrical Generation of Areas.

Our instrument teaches us, if the 'rod' QT is moved one way, the 'roll' of the wheel will increase, whilst it will decrease when moved in the opposite sense. Hence we must consider the 'sense' in which the motion takes place; we shall call the one motion *positive*, the other *negative*. At the same time we shall call the area generated positive or negative. It will be seen that in this case alone will the area always be measured by the 'roll.'

If the rod QT is turned round so that Q is above B, and T above A, then on moving the rod from A to C the roll will be *negative*. We therefore say that the area generated is likewise negative.

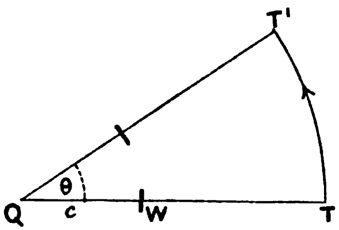
This shows that we must also give the rod QT a definite sense, and we shall take this as positive from Q to T, so that Q is the beginning, T the end of the rod. A reversion of this sense is equivalent to a reversion of the graduation of the wheel. To fix the idea, I shall suppose *that on looking along the rod in its positive sense—i.e.*, from Q to T—*the numbers on the graduation of the wheel increase in the clockwise sense.*

Under this supposition the line QT, when placed anyhow on the paper, will generate a positive or negative area according as it is moved to the left or to the right respectively. This can be put differently.

RULE FOR SIGN OF AREA.

Let the rod, or generating line, QT *pass over a point* P; *then the area near* P *will be positive if to a person standing at* P *and looking along the positive sense of the rod the latter moves from his right hand to his left. The area will be negative if this motion is from left to right.* This rule holds quite independently of the length of the generating line. In fact, as it is stated, a small piece of the line in the neighbourhood of the point which crosses P has alone to be considered. The rule will therefore also hold if the line should vary its length.

FIG. 2.



More than this. Let the line turn about Q as a fixed point from QT to QT′ (fig. 2). It will now sweep over the sector of a circle whose area is $\frac{1}{2}$ QT$^2\theta$ if θ denotes the angle of turning. A wheel W at the distance c from Q will record a roll $w=c\theta$. If QT$=l$, we get, therefore,

$$\text{Area generated} = \tfrac{1}{2}\, l^2\theta = \tfrac{1}{2}\, l^2\, \frac{w}{c}$$

The roll of the wheel will thus again record the area. This will be positive for counter-clockwise turning, negative if the turning is clockwise.

If the wheel should be mounted on the continuation of QT beyond Q, then c will be negative; so will be the 'roll,' and the result will be positive again. It will thus be seen that our rule holds also for this case.

FIRST MODE OF GENERATING AN AREA.

Consider now fig. 3. Let the line QT start at AA′ and move to BB′, the point Q remaining always on OX and QT perpendicular to the latter, whilst T moves along the curve A′B′. The line QT will now generate the area ABB′A′, but in doing so it will continuously change its length.

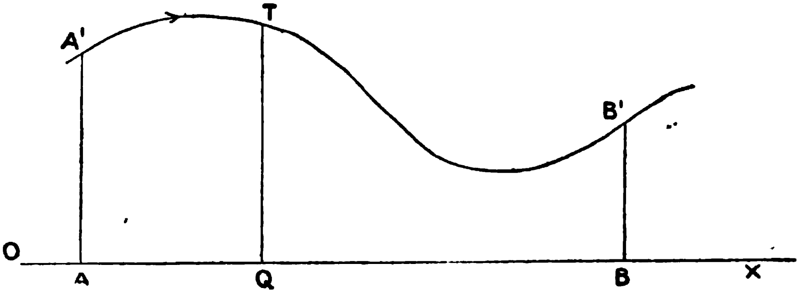
With regard to the sense of the area the rule of sign holds. Hence if, in fig. 4, QT moves from AA′ to BB′, whilst T remains on the lower branch of the curve, it will sweep over the area AA′C′B′B, and this will be negative. But if now the point T moves back to A′ on the upper branch, then the area BB′TA′A will be swept over in the positive sense. The whole area generated will be the difference of these two areas—*i.e.*, it will be the area of the given closed curve.

The point T describes during this process the whole boundary of the area, going always in the same sense along it. If this sense be changed, the motion of QT will also be reversed, and consequently the area will become negative.

This shows that *the sense of an area is determined by the sense given to its boundary;* and, further, that *the area is positive if it lies to the left of a person who goes round the boundary in its positive sense.* If it lies to the right it will be negative.

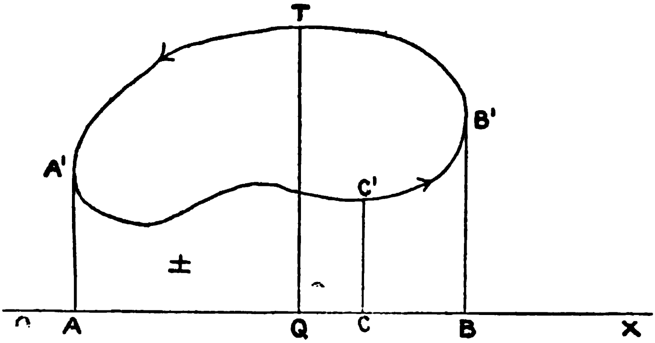
In the application of the Integral Calculus to the evaluation of areas the rule of sign generally adopted is in case of rectangular co-ordinates the reverse to the one here adopted; in using polar co-ordinates, however, it agrees with it. As it would be very inconvenient to use here two rules, a choice had to be made; and I consider on the whole the rule adopted as the one most generally useful.

FIG. 3.



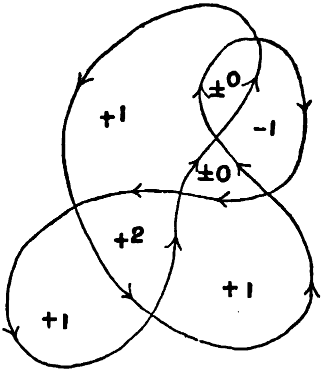
If the closed curve cuts itself, as in fig. 5, take anywhere in the plane a line OX, not shown in the figure, then a point T on the curve, and draw the perpendicular TQ to OX. On moving T along the whole curve till it returns to its starting-point the line QT will sweep over a perfectly definite area, and this is taken as the area enclosed by the given curve. To see what it means we may apply again the rule of sign and see how often and in what sense the line QT passes over any given point. It will be found that every point without the curve is passed over either

FIG. 4.



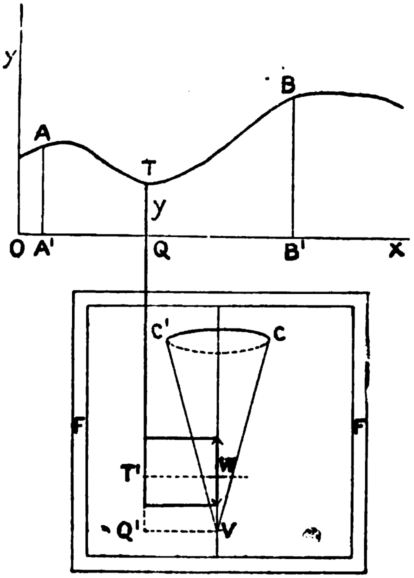
not at all, or else as often in one as in the opposite sense. Each separate part in which the plane is divided by the curve will be swept over a certain number of times, which is easily determined by applying the rule. In the figure these numbers are inserted.

Fig. 5.



This generalisation of the meaning of an area has long been adopted in geometry, principally through the writings of Möbius. According to Cremona, it was first given by De Morgan.[1]

Fig. 6.



To build a planimeter on these geometrical lines we have to add a suitable recording apparatus. The simple wheel rolling on the paper is not any longer sufficient, as the length of the generating line or 'rod' QT varies.

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[1] *Cambr. and Dublin Math. Journ.*, vol. v. 1850.

But if the wheel is made to turn faster in proportion to the length QT, we should have what is wanted. This was obtained in the first planimeter by making the wheel run on a cone.

The diagrammatic drawing (fig. 6) will simplify the description.

A frame FF is made movable in the direction of the line OX, either by letting it run on rails or by giving the wheels milled rims. On it rests a rod T′T perpendicular to OX, which can slide to and fro in its own direction. It ends at T in a tracer which can be made to follow any curve. The frame also carries a cone VCC′, whose axis is inclined to the paper, so that the upper edge is horizontal. Its rim CC′ rests on the paper, so that it turns when the frame moves, and this turning will be proportional to the forward motion. Mounted on the rod, or, as in the figure, on an axis parallel to the rod, is a wheel W resting on the upper edge of the cone.

If the rod is pushed back till the wheel W comes to V, the vertex of the cone, then T will come to Q on the line OX. On moving T along this line the wheel will not turn. But if T is pulled out a distance $QT=y$, then the wheel will assume a position W in the figure such that $VW=QT=y$. On moving the frame forward the roll of the wheel will be proportional to y and to the forward motion. Hence if the tracer T is guided along a curve from A to B, then the roll will be proportional to the area between the curve and the axis OX.

Taking rectangular co-ordinates $OQ=x$ and $QT=y$, we have in the symbols of the Integral Calculus the above area$=\int_A^B ydx$, and the roll of the wheel will be proportional to this.

This planimeter follows in its construction the determination of an area in the Integral Calculus using rectangular co-ordinates. Planimeters of this type have therefore been called *orthogonal planimeters* (Dr. A. Amsler).

If the tracer is moved round a closed curve the instrument gives the enclosed area, but it is worthy of notice that the reading has also a meaning if the curve is not closed.

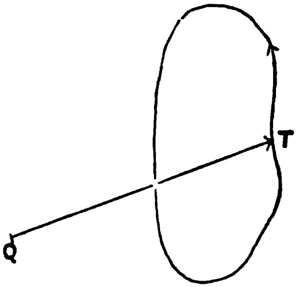
SECOND MODE OF GENERATING AN AREA.

If a line QT of constant length turns in the plane of the paper about its fixed point Q, it will sweep over a sector of a circle. If this generating line has, as before, a positive sense from Q to T, it will be seen at once that the area swept over will be positive or negative according as it turns in one or in the opposite sense. It will also be seen that our rule of sign will again serve to determine the sense, and that this will still hold if the length of QT is variable.

From this it follows :

If a line QT *of variable length turns about its fixed end* Q, *then the area generated by it whilst* T *describes a closed curve will be equal to the area bounded by this curve.*

FIG. 7.



For our rule shows at once that every point within the curve, if this does not cut itself, will be passed over once (fig. 7), every point without the curve either not at all or as often in one sense as in the other. The point Q may be either within or without the area.

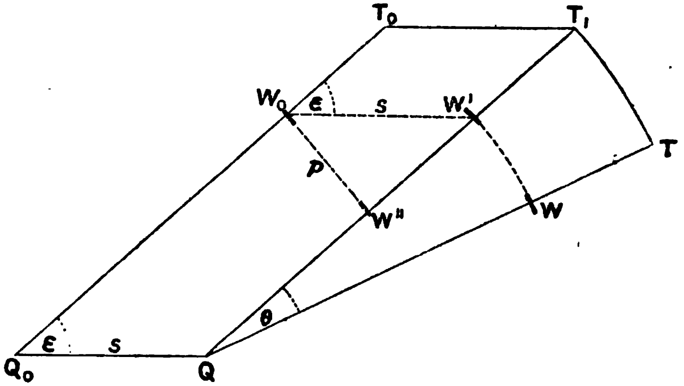
If the curve cuts itself, the area swept over will be the same as in the former case (fig. 5), and all the remarks made there will be applicable.

This is the mode in which areas are generated when using polar co-ordinates. Planimeters based on this principle might therefore be called polar planimeters. But as this name has been appropriated for an altogether different type, I call these simply planimeters of Type II., or *Polar-co-ordinate Planimeters.*

THIRD MODE OF GENERATING AN AREA.

Whilst in the last two cases an area was generated by a line of variable length which had either a motion of translation or a motion of turning alone, we shall now suppose that a line has both motions but a constant length.

FIG. 8.



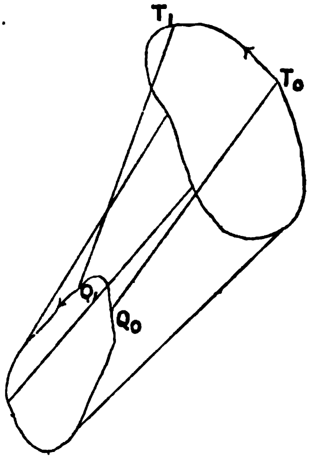
Let QT again denote the generating line now of constant length l. Let it be moved from the position Q_0T_0 (fig. 8) to a near position, QT. This motion can be decomposed into a small translation to QT_1 and a turning about Q which brings it to its final position, QT. For both these motions our rule of sign holds; it will therefore also hold for the actual motion of the line where both motions go on simultaneously. On applying the rule the following theorem will be seen to be true in which a motion of a line is called cyclical if it ultimately returns to its initial position (compare fig. 9).

Theorem I.—*If a line* QT *of constant length performs in a plane a cyclical motion, then the area generated is equal to the area enclosed by the path of the end point* T *diminished by that enclosed by the path of* Q, *both areas being taken in their proper sense as determined by the sense in which each boundary is described.*

Corollary.—If the point Q *is moved to and fro along a curve so that its path does not enclose an area, then the area generated will be equal to the area enclosed in the path of* T.

The measurement of this area is much facilitated by the following considerations. Let p denote the perpendicular distance between the position Q_0T_0 and QT_1, and θ be the angle through which the rod is turned. The area generated by the first step, the translation, is then $= lp$, the area of the sector is $\frac{1}{2} l^2\theta$. The whole area swept over by the rod is the sum of the areas due to the successive elementary steps. It consists, therefore, also of two parts, the first being due to the elementary translations and equals $l\Sigma p$, where Σp is the sum of all the lateral displacements of the rod. The second part consists of the sum of all the sectors of circles described by the turning of the rod, and equals $\frac{1}{2} l^2\Sigma\theta$, where $\Sigma\theta$ denotes the sum of all the elementary turnings, and this is the same as the total turning of the rod. But the rod returns to its original position. The angle $\Sigma\theta$ is therefore either $= 0$ or it is a multiple of 2π, which will happen if the rod has turned round once or several times. This gives—

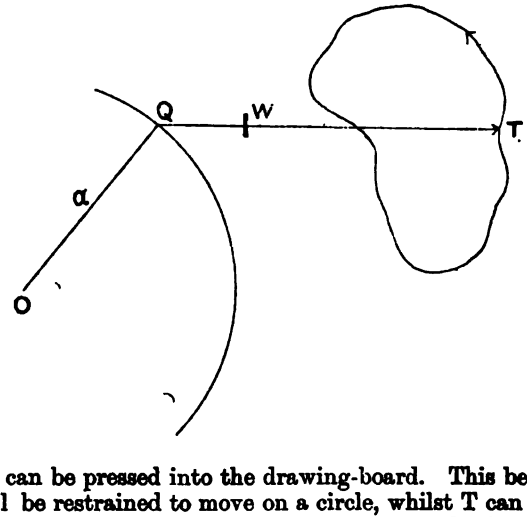
FIG. 9.



Theorem 2.—*If a rod of finite length performs a cyclical motion without itself making a complete rotation, then the area swept over equals that generated by the successive motions of translation only; but if it completes* n *rotations, then to this quantity has to be added* $n\pi l^2$, *i.e.*, n *times the area of a circle of radius* l.

To construct a planimeter on these principles, let the rod QT be connected by an articulated joint at Q to another rod OQ, which shall in future be called the 'arm' (fig. 10). Let this arm have at O a needle point which can be pressed into the drawing-board. This being done, the point Q will be restrained to move on a circle, whilst T can be guided by hand along any curve. The point O is called the *pole* of the instrument and the latter is therefore generally called a *Polar Planimeter*.

FIG. 10.



Let, now, T be moved round a closed curve whilst the pole is outside its area (fig. 10). The point Q moves to and fro along the circle and returns to its original position when T does so. The motion of the rod will therefore be cyclical. An exception can only occur if during the motion rod and arm should become stretched out to their fullest extent, and on moving on, Q should be allowed to move the wrong way. This can always be easily avoided.

The corollary to Theorem 1 is therefore applicable. It says that the area is equal to the area generated by the rod QT. But this area, according to Theorem 2, equals the area generated by the motions of translation alone, and this can be recorded by a simple wheel. Let there be mounted anywhere on the rod a wheel W, at a distance c from Q.

If a small motion of the rod be decomposed as before (fig. 8), the wheel will move along the line W_0W' during the translation and along the arc $W'W$ during the turning. The first may again be decomposed in the motion from W_0W'', whereby the rod describes the area pl whilst the wheel rolls, the amount of its 'roll' measuring p, and the motion $W''\ W'$, during which the rod slides along itself and the wheel slips along the paper without rolling.

Fig. 11.

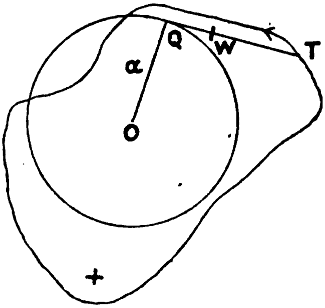
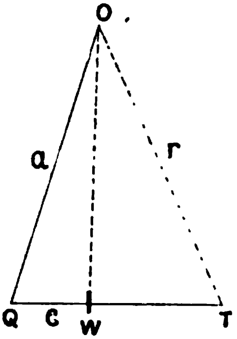


Fig. 12.



During the turning the wheel will roll along the arc $W'W=c\vartheta$. The whole roll during an elementary step, which will be denoted by w, is therefore

$$w=p+c\theta,\ \therefore p=w-c\vartheta$$

We found the area swept over

$$=lp+\tfrac{1}{2}\,l^2\theta$$
$$=lw+(\tfrac{1}{2}\,l^2-cl)\vartheta$$

For the whole area A we have, therefore,

$$A=l\Sigma w+(\tfrac{1}{2}\,l^2-cl)\Sigma\vartheta$$

In the case under consideration $\Sigma\theta=0$. At the same time Σw is the whole roll of the wheel. If we denote this simply by w, we get

$$A=lw$$

In the case where the pole lies within the area, as in fig. 11, we have

$\Sigma\theta=2\pi$, and consequently the area generated by the rod is the area A enclosed by the curve less the area of the circle with radius $OQ=a$. The former is $lw+(\frac{1}{2}l^2-cl)\,2\pi$. In order to get A, the area $a^2\pi$ of the circle has to be added. This gives

$$A=lw+(a^2+l^2-2cl)\pi$$

or writing

$$a^2+l^2-2cl=r^2$$

we have

$$A=lw+r^2\pi$$

Here $r^2\pi$ is dependent on the dimensions of the instrument only, and is, therefore, for each instrument a constant C, so that

$$A=lw+C$$

The geometrical meaning of this constant is easily found.

If the instrument is placed in such a position that the plane of the wheel passes through the pole O, we get, as in fig. 12,

$$r^2=a^2+l^2-2ac$$

$C=r^2\pi$ is therefore the area of a circle with the radius r thus fixed. In fact, if T is moved round the circumference of this circle the wheel will slip over the paper without rolling. Therefore, $w=0$ and $A=C$, as it ought to be. This circle is sometimes called the Base-circle.

It may be noticed also that for any other path of T the wheel will always turn and slip. The amount of this slipping during the small motion considered before (fig. 8) is equal to $W''W'$, or if s denotes the length Q_0Q, and ϵ the angle which the axis of the wheel makes with the direction W_0W' of its motions, then

the roll is $p=s\sin\epsilon$,
the slipping $S=s\cos\epsilon$.

HISTORY OF PLANIMETERS UP TO 1856.

From an article published by Bauernfeind, of Munich, in Dingler's 'Polytechnisches Journal,' vol. 137, p. 82, it appears that the Bavarian engineer J. M. Hermann invented a planimeter in 1814. This was improved by Lämmle in 1816, and carried out in the following year. Nothing, however, was published about it, and the instrument was forgotten, without having any influence on the further history of the planimeter and its development.

In 1824, the Italian Tito Gonnella, professor at Florence, invented a planimeter very much on the same lines as Hermann—viz., an instrument of Type I.

In the following year he published 'Teoria e descrizione d' una macchina colla quale si quadrano le superficie piane. Dall' Antologia . . . dell' anno 1825. Tomo 18. Al gabinetto scientifico e letterario di G. P. Vieusseaux, Firenze, direttore ed editore. Tipografia di Luigi Peggati, 1825, Firenze.'

This paper is short and without figures. Later on he gave a fuller description in his 'Opuscoli Matematici' (Firenze, 1841). Both publications appear to have remained practically unknown till Professor

Anton Favaro, of Padua, called attention to them in his 'Beiträge zur Geschichte der Planimeter' ('Allgemeine Bauzeitung,' Wien, 1873). In this paper it is pointed out that Gonnella, even though anticipated in the invention by Hermann, was the first to publish anything about a Planimeter.

His first instrument was of Type I., with the recording wheel rolling on a cone as described. Soon after he replaced the cone by a disc.

Gonnella had one instrument made, but it seems he was unable from the want of skilled labour in Florence to obtain a well-executed piece of mechanism. When the Archduke of Tuscany wished to add a well-made planimeter to his collection, Gonnella looked for its execution to Switzerland, where the flourishing watch industry had developed accurate workmanship. He accordingly sent, in 1825 and 1826, through a Florence merchant, numbers of drawings to different firms in Switzerland, without, however, succeeding in getting what he wanted.

In 1826 the Swiss engineer Oppikofer invented a planimeter, and this was made in the following year. How much he had heard of Gonnella's invention or of Hermann's cannot now be decided. It is, of course, quite possible that he should have made an independent discovery. Bauernfeind estimates that at that time about a billion areas had annually to be evaluated in Europe. He also gives in the paper quoted a pretty long list of various contrivances for facilitating this work, and which, by the way, were called planimeters (they were not integrators). The problem was, therefore, one that pressed for a solution, and it would be quite in conformity with other instances in the history of science that several men should perfectly independently make the same invention. Nevertheless, there is a possibility if not probability that Oppikofer should have heard of Gonnella's invention. Anyhow, it is his instrument which became the starting-point of the further development of planimeters.

Oppikofer, it seems, put himself in communication with the mechanician Ernst in Paris (before 1836) to introduce the instrument in France. Thus it comes that planimeters of Type I. are known in France by the name of Ernst, who improved them and made them practical instruments. He retained the wheel rolling on a cone, although Gonnella had already in 1825 replaced the cone by a horizontal disc. Ernst received, in 1837, a portion of the Montyon Prize as a reward.

It will be remembered that the cone allows only of positive ordinates of the curve. The engineer Wetli, of Zürich, tried (1849) to remedy this by using two cones with their vertices opposite, so that the upper edges of both formed one straight line. In order to make the path for the wheel continuous he meant to cover both with one disc to be turned by the cones. But then he found, of course, that he could do without the cones if only he drove the disc so that its rotation was proportional to the side motion of the line QT. Having the idea of the disc given, we see at once that this disc is only a special case of a cone which has degenerated into a plane, but it is always of interest to learn the roundabout way in which improvements are made.[1]

This improvement was, as has already been mentioned, anticipated by Gonnella, but was now introduced practically. Disc-planimeters were made by Starke in Vienna under the name of Wetli-Starke Planimeters. They were improved by the astronomer Hansen, of Seeberg, near Gotha, and became, as executed by Ausfeld in that town, instruments of very great accuracy, known as the Wetli-Hansen Planimeters. A description with figure is given by Bauernfeind in the 'Proceedings' of the 'Polytechnischer Verein für das Königreich Bayern,' 1853, pp. 130–147, and 213–244. The figure is copied in Prof. Dyck's 'Catalogue of the Mathematical Exhibition,' Nachtrag, p. 32, Munich, 1893.

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[1] These data concerning Wetli's invention of the disc I owe to Coradi, to whom the late Professor Harlacher in Prag had communicated them.

The disc is turned by aid of a silver wire which is attached to the rod QT and slung round a pulley on the axis of the disc, so that here rod and carriage have interchanged their *rôle*.

Among Hansen's improvements one may be mentioned, as I have recently heard of it as a new American improvement. The tracer T is replaced by a piece of glass with a small circular mark on it which is guided along the curve. A lens above the glass serves to make the guiding more accurate. This form of a tracer is, however, straining to the eye, and seems only of use where areas have to be determined with great accuracy.

In England, John Sang made a planimeter which is described in the 'Civil Engineer and Architect's Journal,' 1851, p. 505, and also in the 'Transactions' of the Royal Scottish Society of Arts, vol. iv. Bauernfeind says that it differs from that by Ernst 'fast gar nicht.'

It was exhibited at the Great Exhibition in 1851, and obtained honourable mention, whilst Gonnella received a Council medal and Wetli a prize medal. Ausfeld also exhibited a planimeter, which is described as invented by Dr. Flaussen (probably an error for Hansen), of the Observatory of Seeberg. Of this instrument, which received honourable mention, I have not found any further description than that it had a wheel rolling on a disc. It was most likely the modification of Wetli's, referred to above.

These exhibits are of importance in the history of planimeters, because they drew Maxwell's attention to the subject, on which he communicated early in 1855 a paper to the Royal Scottish Society of Arts ('Transactions,' vol. iv., and 'Collected Papers,' vol. i. p. 230). In this he points out the deleterious effect of the *slipping* of the recording wheel on the cone or disc, and then proceeds to the description of a new recording apparatus, in which the wheel rolling on a cone or disc is replaced by a sphere, which rolls without slipping on an equal sphere. It is a most beautiful contrivance, but it has never been carried out. It may, however, be considered as the starting-point of all integrators which work without slipping.

Maxwell describes two planimeters having this new contrivance, the one belonging to Type I., the other to Type II.

About this time Josef Stadler, of Eisenerz, in Styria, constructed a planimeter of peculiar character. It works without slipping, and is in many respects of interest on account of the peculiar integrating apparatus used.

The tracer T is fastened to a bar whose motion is constrained to remain parallel to the axis of x. Rigidly connected with this is a thin cylinder, which can turn about an axis parallel to the bar, hence to the axis of x. This cylinder rests on a surface of revolution movable about its axis a, which is parallel to the axis of y. If the tracer be moved in the direction of the y, the cylinder will roll along a meridian curve of the surface of revolution, but the latter will remain at rest. A motion of the tracer in the direction of the x will pull the cylinder across the surface of revolution, and therefore make it revolve to an extent which is proportional to the distance of the point of contact from its axis a. If z denotes this distance, and y the distance of the tracer from the axis of x, *i.e.*, the generating line

QT, then the turning of the surface of revolution will measure the area, provided that zy remains constant. In order that this condition may be satisfied, the meridian curve of the surface of revolution must be a solution of a differential equation of the first order and the second degree. An integral of this equation cannot be found in a finite form, but an equilateral hyperbola revolving about an asymptote satisfies the condition very nearly. In the instrument made this hyperbola was corrected by actual trial. It will be seen that there is no slipping. The difficult construction of the surface of revolution makes it doubtful whether a very great accuracy is obtainable. But as Dr. A. Amsler, who called my attention at the Munich Exhibition to this model, pointed out to me, the principle might be useful in the construction of integrators designed for special purposes.

Stadler had a first, and as it seems an only instrument made in 1855, which is now in the possession of the Technische Hochschule in Gratz. It was exhibited in Munich. Stadler published an account of it in the journal 'Erfahrungen im berg- und hüttenmännischen Bau- und Aufbereitungswesen,' edited by Rittinger, 1857. It seems to have remained practically unknown till the Munich Exhibition. In Dyck's 'Catalogue' is a full account of it by Professor Lichtenfels, of Gratz.

It appears that Stadler, in the out-of-the-way place where he lived, had heard of planimeters, but was not acquainted with their construction.

PLANIMETERS OF TYPE II.

Of Polar-co-ordinate planimeters Amsler mentions three (Appendix to his paper of 1856) proposed by Gierer, of Fürth,[1] by Bouniakovsky, of St. Petersburg, and by Decker, of Augsburg (the last two described in Dingler's 'Pol. Journ.,' vol. cxl.). Each has a recording wheel rolling on the paper whose axis passes through a fixed point Q, whilst its distance from Q is always proportional to the square of the distance of the tracer T from Q. In Gierer's instrument the wheel is kept in the required position by aid of a guiding curve, in the other two by aid of link-work.

One of Maxwell's planimeters belongs to this type, and so does one by C. V. Boys.[2] Both were invented with the object of avoiding all slipping in the recording apparatus, which is too complicated for an instrument designed simply for the determination of areas.

Lastly, there is an instrument described by W. R. Bousfield in the discussion of Hele-Shaw's paper 'On Mechanical Integrators.'[3] In it guide curves are used.

None of these planimeters has, so far as I know, ever been made. Of Boys' a model is to be found in the Science collection at South Kensington.

AMSLER'S PLANIMETER AND ITS DEVELOPMENT.

Whilst planimeters of Type I. were gradually reaching a state of great perfection, Amsler invented his polar planimeter, which, in consequence of its simplicity, handiness in use, and low price, soon drove all the older forms, which, when well made, were necessarily expensive, out of the field.

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[1] *Programm der Gewerbs- und Handelsschule zu Fürth*, $18\frac{53}{54}$.

[2] *Phil. Mag.*, 1882, p. 83.

[3] *Proc. Inst. Civ. Eng.*, vol. lxxxii. part iv.

Jacob Amsler, as I have been told by the late Prof. Hesse, was at the time a student at Königsberg, where Prof. Franz Neumann encouraged his students to work at the lathe and otherwise use their hands. He thus was enabled to make his first instrument with his own hands in about 1854. His first publication about it is 'Ueber die mechanische Bestimmung des Flächeninhalts, der statischen Momente und der Trägheitsmomente ebener Figuren, insbesondere über einen neuen Planimeter,' 'Vierteljahrsschrift der naturforschenden Gesellschaft in Zürich,' 1856; also in Moigno's journal, 'Cosmos,' February 29, 1856. This planimeter is so well known that no description is necessary beyond what has been said already about planimeters of Type III. Many thousands of them have been manufactured by Amsler at his works in Schaffhausen, and though in England many are sold with the name of an English firm engraved on them, practically all have come from Schaffhausen.

The instrument has practically remained unaltered since its invention.

It is made either with a rod QT of invariable length, giving the area, say, in square inches, or with a rod of which the length may be changed so that the same instrument can be set to give the area in different units.

To the latter Amsler has added on the top of the rod a pointer, and another on the 'sleeve' in which the rod slides. These are at a distance equal to that between the tracer T and the joint at Q. It is thus possible to set the instrument so that the length l of the rod equals the greatest extension, parallel to a given line, of the area. The reading of the instrument is then proportional to the mean height of the area perpendicular to that line. This is especially useful for finding the mean pressure directly from an indicator diagram.

Mr. Druitt Halpin has added a simple locking gear to the recording wheel, so that the instrument can be taken up without moving the wheel. This has the advantage that the instrument can be placed in a good light for reading, but it is also particularly useful in cases where the mean pressure, as determined from a great number of indicator diagrams, is required. The instrument may be set to zero, then locked, placed on the paper, and one diagram after the other run over, the wheel being always locked whilst the diagrams are being changed. The final reading divided by the number of diagrams used gives the mean at once.

For the mere facility of reading another recent improvement is of far greater importance. It consists in replacing the reflecting surface of white metal on which the graduation used to be engraved by the matt white of celluloid with black lines on it.

Of the many theories of Amsler's planimeter which have been given—and their name is legion—most make use of the Integral Calculus.

J. Amsler starts with geometrical considerations similar to those which I have given at the beginning. With these I became originally acquainted through Culmann's 'Graphische Statik.' They give, in my opinion, the quickest access to the real nature of all planimeters.

The other theories serve as examples, and some as very good illustrations, of the use of curvilinear co-ordinates.

Here it may be remarked that the integration as performed by the planimeter gives really a line-integral, and many of the proofs which start with the evaluation of an element of the area are examples of transforming an integral over an area into a line-integral over the boundary; hence they are simple examples of Stokes' Theorem.

Dr. A. Amsler in his valuable paper, 'Ueber den Flächeninhalt und das Volumen durch Bewegung erzeugten Curven und Flächen, und über mechanische Integrationen' (Inaugural Dissertation, Schaffhausen, 1880), starts with proving that the area passed round by the tracer equals

$$l\int \sin a . ds$$

where ds is an element of the boundary and α the angle it makes with the rod, the integration being taken over the whole boundary. It is therefore a true line-integral.

Where the only object is to explain Amsler's planimeter, Macfarlane Gray's theory is perhaps the simplest. It is given in Carr's 'Synopsis of Mathematics.'

In 1855, hence at very nearly the same time as Amsler, Prof. Miller Ritter von Hauenfels invented a planimeter based on the same principles as Amsler's. It is described in the 'Handbuch der niederen Geodäsie' (2nd to 7th ed.), by Prof. Fr. Hartner, and also in Dyck's 'Catalogue,' p. 190. Gustav Starke, of Vienna, simplified the arrangement of the recording wheel, and manufactured 'in the course of years hundreds of them.' It is known as the Miller-Starke Planimeter.

As Amsler's polar planimeter is universally used, the following discussion of its errors may be of interest.

First error: The diameter of the wheel and the length of the 'rod' are not in the proper relation—*i.e.*, if u is the unit division of the recording wheel, l the length of the rod, the product lu does not give the accurate unit of area intended. This error is generally very small. Otherwise all readings have to be multiplied by a factor of reduction.

Second error: The axis of the wheel is not parallel to the rod, but makes an angle ϵ with it.

If W is the 'roll' of the wheel and S the slipping (due to translation of the rod only), the area then is

$$A = l \cos \epsilon . W + l \sin \epsilon . S + n\pi l^2$$

Or, as ϵ is practically very small,

$$A = lW + lS\epsilon + n\pi l^2$$

This introduces an error, $lS\epsilon$, which may be appreciable.

If a rod QT′ be fixed to the rod QT, making an angle ϵ with the normal to the latter and of equal length to it, then, whilst T describes the boundary of the area A, the point T′ will describe another closed curve. The area bounded by this curve is Sl. This area will often be small, but it is easy to draw curves for which it is considerable, by guiding T′ round an area of considerable size. If T circumscribes an area A, and T′ an area A′, then the error S in A will be A′ sin ϵ, and that in A′ will be A sin ϵ.

This error has been investigated by Herr Wilski in 'Zeitschrift für Vermessungswesen,' 1892, p. 610.

In the same journal for 1894, Herr Lang has shown how to eliminate it. About this more will be said presently in connection with the Lang-Coradi Planimeter.

Third error: The axis of the joint at Q between the arm OQ and the rod QT is not perpendicular to the paper—*i.e.*, not parallel to the axis about which the instrument turns at O. See Wilski's paper.

Fourth error : Due to slipping of the wheel. This is the error on which Maxwell dwelt strongly.

This error increases with the amount of slipping, with the friction resisting the slipping, and lastly with the resistance to the turning of the wheel.

In order to reduce this error, the above three causes have to be diminished. This has led to a number of new constructions, which have to be discussed presently. It may here be stated that the third has led to the introduction of a 'disc,' as used in the planimeters of Type I., on which the wheel rolls. The rough paper is, therefore, replaced by a smooth prepared surface.

To reduce the resistance to the turning of the wheel, mechanical skill alone can help.

But to reduce the first cause we have to investigate the amount of slipping at different positions of the rod of the instrument relative to the arm. If it be placed in such a position that the plane of the wheel passes through the pole O, and if now the instrument be moved as a rigid body, then the tracer will describe a circle. At the same time, the wheel will not roll, but only slip. This circle, formerly referred to as the *base-circle*, will be the locus of greatest slipping.

If the tracer be moved along this circle there should be no turning, and there will be none. Hence, on this circle itself, the error due to slipping will be zero. If, however, the tracer be moved on a concentric circle a little inside the base-circle, then rolling will take place in one sense, but on a circle a little outside in the opposite sense. In either case there will be much slipping, causing an error. This error will be proportional to the length of the path of the wheel, *i.e.*, to the roll ; hence, on moving the tracer parallel to the *basec-ircle*, but at an increased distance from it, the error will increase on account of the increased roll, and decrease on account of the decreased slipping. It will soon reach a maximum, and then diminish. The same is true outside the base-circle, only the error will be of the opposite sense.[1]

It becomes thus apparent that the error due to slipping is dependent on the position of the pole relative to the area, and also that with changing the position of the pole the errors change in an apparently haphazard manner.

It is of interest to compare these results with practical tests. Wilski points out that there are certain positions of the pole for which the record of the wheel becomes a maximum, others for which it is a minimum. This is explained by supposing that in these cases a part of the boundary of the area is parallel and near the base-circle either on the one or the other side of it. Wilski seems to attribute it to an obliquity in the joint at Q. Coradi's experiences during more than ten years also reveal these maxima and minima. But he finds them equally in all planimeters where a wheel is used, and draws the conclusion that the error causing them must lie in the wheel and in the resistance to its turning. The slipping he does not mention, but there seems no doubt that in it lies the true dynamical cause.

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[1] I have just (October 30) received from Coradi a paper by Lang (reprint from the *Allgemeine Vermessungs-Nachrichten*, 1894) in which he discusses the errors of an Amsler Planimeter, and remarks that the tracer T can be moved from any position so that the wheel will only slip without rolling. This is obvious when pointed out. These paths are spirals, one through every point, which approach the base circle asymptotically either from within or from without, so that there are two sets of these curves, all of one set being congruent. My reasoning in the text must therefore be extended to these spirals also.

To reduce the error due to slipping no part of the boundary of the area to be measured should therefore be parallel to one of these curves or to the base-circle. Lang recommends to draw one of each of these spirals by trial and to cut it out in stiff paper. By aid of these templets it is then easy to place the planimeter so on the paper that the boundary cuts the base circle and these spirals nearly at right angles.

Fifth error: The axis of the wheel does not lie in the rod QT, but at a small distance sideways from it. This introduces a small amount of extra slipping.

The errors discussed so far depend on the construction, the next on the skill of the manipulator.

Sixth error: Due to wrong guiding of the tracer.

As the tracer has to be guided by hand round the curve, there will always be slight deviations. Of the error hereby introduced not much can be said in general. It depends on the skill and care of the manipulator. The latter should always look as much as possible in the direction in which the tracer moves along its path, so that any deviation may at once be detected. These deviations will, in general, be partly positive, partly negative, so that the errors introduced will greatly cancel each other.

To separate these errors from those due to the instrument it is necessary to guide the tracer mechanically round a known area. For this purpose Coradi uses, and sells with his planimeters, a 'Control-lineal,' consisting of a strip of metal with a line marked along the middle of its length. On this line a series of little conical holes are made to receive the tracer. It can turn round a needle-point at one end, which is pressed into the drawing-board. But to make good tests with it requires some skill.

Elaborate tests of various planimeters have been made in this manner by Prof. Lorber, of Leoben ('Zeitschrift für Vermessungswesen,' 1883 and 1888).

Rules for the accurate use of planimeters and for testing them are also given by Coradi in a pamphlet 'Praktische Anleitung zum Gebrauch, etc., des einfachen Polar-Planimeters,' 2te Aufl., Zürich, 1888.

HOHMANN-CORADI AND LANG-CORADI.

Amsler's polar planimeter remained practically unaltered till the Bavarian engineer F. Hohmann constructed his 'precision planimeter' in 1876. In 1880 he communicated his ideas to Coradi in Zürich, who has since constructed it in a variety of different forms.

The Hohmann-Coradi precision planimeter is of Type III. But the recording wheel rolls on a disc with finely prepared surface. This disc itself is turned by the motion of the point Q of the generating line or 'rod' QT. The wheel rests with light pressure on the disc. The friction to be overcome by the slipping of the wheel is thus greatly diminished.

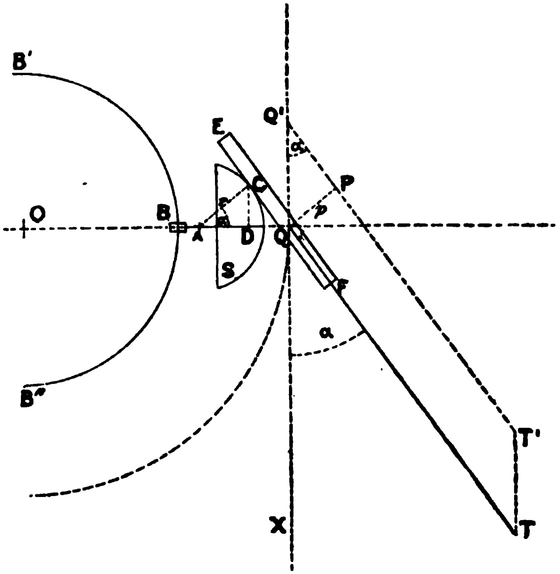
Of the different forms used by Coradi, I mention only the 'rolling planimeter.' The point Q is guided along a straight line by the aid of a carriage which rests on two wheels with milled edges. The motion of the instrument in this direction is thus unlimited. Such wheels without rails had been used already by Sang and by J. Stadler (Dyck's 'Catalogue') for a planimeter of Type III.

Amsler, too, has since 1882 made planimeters with the wheel rolling on a disc.

Soon after the construction of these instruments, Amsler published his paper 'Neuere Planimeter-Constructionen' ('Zeitschrift für Instrumentenkunde,' 1884), which is full of interest. He describes a planimeter in which a wheel rolls on a sphere, and which is designed to measure areas on a sphere or globe instead of a plane. He shows that all known planimeters in which a recording wheel is employed may be considered as special cases of his new instrument. Of course, if the radius of the globe is taken infinitely large, we get a plane.

By introducing a cylinder instead of the wheel he gets an instrument where there is no slipping, and he says that this planimeter is the only one which deserves the name of 'precision planimeter.' This instrument has never been made. In fact, Amsler considers it too complicated, and states that, although he had sold (up to 1884) over 12,000 polar planimeters, only a few hundred of his more complicated Moment-planimeter had been made.

FIG. 13.



Influenced, no doubt, by this paper and the criticism it contained, Coradi made soon after what he calls a 'Precisions-Kugel-Planimeter.' At the cost of retaining a very slight amount of slipping he simplifies Amsler's mechanism considerably, and produces a simple and handy instrument, of which in four years, up to 1892, over 450 have been sold. It is made in two forms. In the one, the point Q of the 'rod' QT moves in a circle; in the other, along a straight line, it being mounted on a carriage with two wheels.

I shall describe the former. A heavy disc with centre O, fig. 13, has a raised circular rim B'BB'' with small teeth. Round O the 'arm' OQ is movable, and at Q the 'rod' QT is jointed to it. This gives an ordinary polar planimeter; if T is moved round the boundary of an area which may be denoted by (T), then the rod QT will sweep over an area equal to (T) which has to be registered. This is done by the 'roll' of a cylinder EF, whose axis is parallel to the 'rod.' This cylinder does not roll on the paper, but on a spherical surface S. The latter can revolve about a horizontal diameter AD which is parallel to the arm OQ, and which has at B a small toothed wheel gearing in the rim B′BB″ of the fixed disc. Let the cylinder EF touch this sphere at C in the horizontal great circle, and let A be the centre of the sphere. If now the rod and with it the axis of the cylinder make an angle a with the tangent QX to the circular path of Q, then the distance of the point C from the axis of the sphere will be $CD=r \sin a$, where r is the radius of the surface S. Let now the rod QT get a small translation to Q′T′, sweeping over a small area $QTT'Q'=lp$. Of course, QQ′ must be so small that it may be considered an arc of the circle in which Q moves. If $QQ'=x$, then is $p=x \sin a$, the area $QTT'Q'=lx \sin a$. At the same time OQ will turn about O through an angle proportional to x, and this will produce a rotation of the sphere and a motion of C proportional to CDx, *i.e.*, proportional to $x \sin a$ or to p. This will be communicated to the cylinder. Hence the roll of the cylinder during a small motion of T will be proportional to the area swept over by the rod during the *translation* of the rod. According to the general theory of planimeters of Type III., the 'roll' of the cylinder measures the area enclosed by the path of T, provided that the rod does not complete a whole rotation. If the point O should lie within the area, a certain constant has to be added to the 'roll' of the cylinder, as in Amsler's simple planimeter.

This very simple theory is, however, not quite correct. For if QT turns about Q the cylinder will not always touch the sphere. To insure a continuous contact the cylinder is mounted in a small rectangular frame, which itself can rock to and fro about an axis parallel to that of the rod.

Amsler, in the planimeter mentioned, places Q at the centre A of the sphere and suspends the frame with the cylinder from above the sphere. In this case a turning of the arm will make the cylinder slip along the horizontal great circle. To avoid this slipping he makes the cylinder movable along its axis, and gets thus an instrument without slipping. Coradi places the point Q so that when the rod is in the direction of QX the cylinder touches the sphere when its axis is vertically above Q. If now the rod be turned about Q, the cylinder with its frame will be pushed sideways, whilst the point C will move below the horizontal great circle. This up-and-down motion of C will produce a roll of the cylinder, the total amount of which, however, will reduce to zero when the point C comes back to its original position, and this it will do when the tracer has described a closed curve.

But this lowering of C also increases the radius CD. At the same time the cylinder will not receive the full motion of the point C. In fact, this motion will be decomposed into rolling and slipping. The rolling will be just the same as if C was still on the horizontal great circle, and will therefore give the area correctly. The slipping will always be very small. There will also be slipping when the rod turns about Q, but this again will be very small. Although the exact determination of these quantities is not difficult, I prefer to refer the reader to A. Amsler's essay, 'Ueber mechanische Integrationen,' in Dyck's 'Catalogue,' p. 107, where a very elementary theory of this part of Coradi's planimeter is given, and also (p. 105) a description of his father's planimeter without slipping.

THE LANG-CORADI PLANIMETER.

Coradi has quite recently constructed a new modification of Amsler's Polar-planimeter which he calls 'Compensations-Polar-planimeter.' Its object is to eliminate the error due to a non-parallelism between the axis of the wheel and the rod QT according to a method due to Herr Lang, a surveyor of Neuwied. The Swiss patent is dated from October 3, 1893. A description of it is published by Lang in the 'Zeitschrift für Vermessungswesen,' 1894, Heft 12.

Lang points out that the error mentioned can be eliminated by going twice round the boundary of the area in the following manner. To fix the idea let the pole O of an ordinary Amsler planimeter be below the curve, the tracer T on it; then the point Q will be to the right. In this position the tracer is moved round the curve. Then, with the same position of the pole, the planimeter is set so that the point Q comes to the left and the tracer is guided again along the curve. The error in question will be equal but opposite in sign for the two operations, and is therefore eliminated on taking the mean.

In Amsler's planimeter this second position is not possible. To make it possible Coradi does not connect the rod QT by a hinged joint to the arm OQ, but by a spherical joint. One wheel is placed slightly on one side of the rod near Q, and another supporting wheel is placed on the other side of the rod with its axis perpendicular to the rod. The rod therefore rests with these two wheels at the one end and the tracer at the other end firmly on the paper. At Q the rod has a hole, with a spherical bottom, open at the top. The arm OQ has at Q a tooth projecting downwards whose spherical end is placed in the hole of the rod. The arm is therefore above the rod, and this requires a new construction of the needle point at O. It consists of a heavy foot having its lower surface in the form of a cylinder whose horizontal edge is perpendicular to OQ. In the middle of this edge is the needle. This arrangement avoids at the same time any obliquity in the axis of the joint at Q. Besides, it is easier handled in taking it in or out of its box, as it consists of two quite separate parts, and thus there is less likelihood of damaging the instrument.

It seems to be an instrument as carefully thought out as it is executed, and will, most likely, replace the more expensive precision-planimeters.

THE HINE-ROBERTSON PLANIMETER.

Within the last few years a new little planimeter has been made by Messrs. Hine & Robertson, of New York, stated to be 'on an entirely new principle.' The principle is however already given by Amsler in his paper of 1856.

Suppose in an ordinary Amsler planimeter a bar CD fixed rigidly at C to the rod QT and at right angles to it. On this bar let a wheel be mounted so that it can turn about it and also slide along it. Let the rim of this wheel be made with a knife edge; then the wheel can only roll on the paper, but instead of slipping on the paper it will slide along the bar. If the wheel had a smooth rim and could not move along its axis we should have the arrangement mentioned before (p. 510), when it was pointed out that its slipping would equal the 'roll' of the ordinary recording wheel. It follows that the displacement of the wheel along the bar equals the 'roll' of the ordinary wheel, and can therefore be used in its place to measure an area.

Amsler describes, in the paper quoted, a planimeter of this kind; but instead of making the knife-edge wheel slide along the bar CD, he makes the bar slide across the rod QT, fixing at each end a knife-edge wheel.

Just as in Amsler's Polar-planimeter the axis of the recording wheel must be parallel to the rod, so the axis of the knife edge wheel must be perpendicular to it. If it deviates from it by an angle ϵ, and if S denotes the sliding, W the rolling of the wheel, then the area will be

$$Sl \sin \epsilon + Wl \cos \epsilon$$

In the Hine-Robertson planimeter the point Q is not guided in a circle but along a straight line. The whole instrument is small, and is contained in a box seven by eleven inches. At the bottom of the box, along one edge, a strip of metal is fastened with a V-groove in it. In this the one end Q of the rod slides. The paper with the indicator-diagram, for which the instrument is meant to be used, is clamped to the bottom and everything ready. The wheel slides, as described, along the bar, which is so graduated that the wheel is set to zero when pushed towards the rod as far as it will go. The instrument is therefore very handy; but it has one fault—the axis of the wheel is not perpendicular to QT.

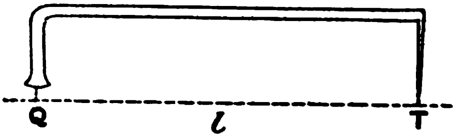
The rod is at the end towards Q bent to a curve, and only the piece in CT, where C is the point of junction with the bar carrying the wheel, is straight. This bar, which should be perpendicular to QT, is so to CT, and makes with QT an angle $\epsilon = 10°$ nearly. If it gives, nevertheless, good results this must be due to the fact that the errors nearly cancel each other.

If the instrument be so placed that CT is parallel to the V-groove, and the line over which CT lies be marked on the paper, then the error will be positive when the tracer is on the one side of this line, negative when on the other. As from the very dimensions of the instrument this line will almost always cross the indicator-diagram, such cancelling of the errors will be explained. But there seems to be no reason why the axis of the wheel should not have its proper position.

THE PRYTZ OR HATCHET PLANIMETER.

This planimeter belongs geometrically to Type III., but the recording apparatus is altogether different from Amsler's. It is curious in its simplicity, consisting simply of a single rod of metal, without any wheel or other movable part. For the ultimate reading an ordinary scale is used.

FIG. 14.



A metal rod is bent as in fig. 14. At T it ends in a point which serves as tracer. At Q it is flattened to a knife-edge, whose plane passes through T. This is placed in a vertical plane with T and Q resting on the paper.

The knife-edge prevents Q from moving sideways. The only motions possible are therefore a sliding in the direction of QT together with a turning about Q. Hence, if T is moved along any curve, Q will follow, always moving towards T. The Q-curve, as the path of Q may be called, is therefore a curve of pursuit. The line QT is always tangential to it. Its length will be denoted by l.

To use this instrument as a planimeter the inventor gives the following rules :—

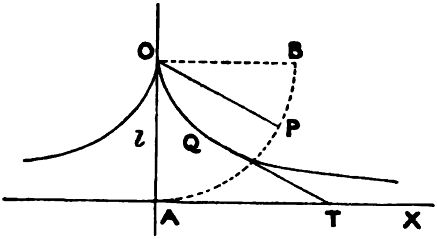
If the greatest extension of the area exceeds $\frac{1}{2}l$ the area has to be divided and the parts measured separately.

Take a point R as near as you can guess to the centre of gravity of the area, and join it to a point A on the boundary ; put the tracer T on R, and make with the knife-edge a mark on the paper. Next guide T from R to A, round the boundary and back to R ; make again a mark with Q, and measure the distance c_1 between these marks. Next turn the instrument through 180° about R and guide T as before, but in the opposite sense, round the boundary. Let the distance between the marks in this case be c_2. Then is the area given by

$$\frac{c_1+c_2}{2}\,l\left(1-\left(\frac{N}{2l}\right)^2\right)$$

where N^2 denotes the mean value of the squares of the distances of R from the boundary. He then adds a table giving $(N/2l)^2$ for different values of N/l. They vary from ·002 to ·016, and are therefore small.

FIG. 15.



He afterwards gives his theory. This leads him to an integral for the area swept over by QT, which cannot be worked out in a finite form, and has to be expanded in an infinite series of which the first terms lead him to the result stated.

The same problem has also been treated analytically by Mr. F. W. Hill in a more elegant manner, the result being given in a slightly different form.

These investigations are, however, somewhat unsatisfactory. It seems to me that the following geometrical reasoning affords us a deeper insight into the real nature of the theory of this instrument.

If T describes a straight line AX (fig. 15) whilst Q starts from O, where AO is perpendicular to OX, then Q will describe a curve known as the tractrix, which will extend to an infinite distance to the right, having AX as asymptote. If T is moved to the left, Q describes the other half of tractrix, which has a cusp at O. Similarly, if T describes any curve, Q will describe a curve which will have a cusp whenever QT becomes normal to the T-curve.

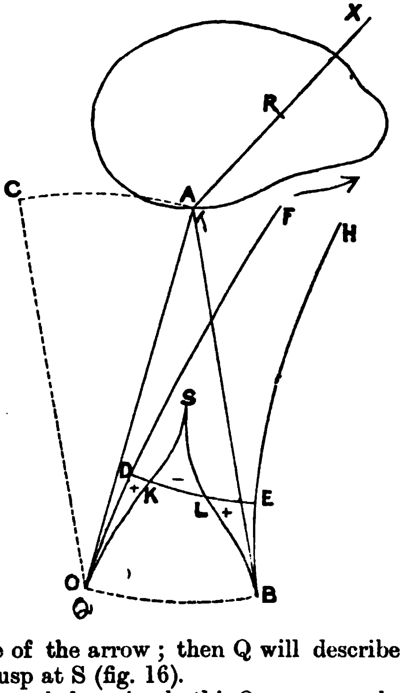
If we decompose a very small displacement of QT during this motion into a sliding along QT and a turning about Q, then the latter alone will generate an area, and if the rod turns through a small angle θ the area generated equals $\frac{1}{2}l^2\theta = \frac{1}{2}la$ where $a = l\theta$ is the small arc described by T during this turning.

Hence, if a line OP=QT be drawn from any fixed point O and kept always parallel to QT it will generate an area equal to that generated by QT itself. Thus in fig. 15 the area OATQO equals the area of the circular sector OAPO if OP is parallel to QT.

In particular, if T is moved to an infinite distance, QT will fall into AX, and will be parallel to OB; from which follows at once the well-known result, that the area between the tractrix and its asymptote from the cusp to infinity equals that of a quadrant of a circle with radius l.

Let now a closed curve be given, A a point on it, and let the planimeter QT be placed in the position OA. Next let T be moved from A round the curve in the sense of the arrow; then Q will describe a curve somewhat like OSB with a cusp at S (fig. 16).

FIG. 16.



If the given curve is less simple this Q-curve may be more complicated, but the following reasoning will always hold.

The area described by QT is found to be equal to that of the section OAC, where OC is parallel to BA. In order to make the Q-curve closed, suppose the line QT turned about A from AB back to AO. Hereby the sector BAO is described, which equals OAC both in magnitude and sense, for the sense of QT is from Q to T; hence from B to A.

We have now a cyclical motion for QT. According to Theorem 1

(p. 502) the area generated equals (T)−(Q), where (T) is the area of the given curve and (Q) the area of the closed Q-curve, or equal to twice the sector AOB, *i.e.*, equal to $l.a$, where a denotes the arc OB. If we now could vary the proceeding so that (Q)=0 we should have (T)$=la$, and need only measure the arc a to get the area of the given curve.

To do this draw from A any straight line AX, place the planimeter in its original position OA, and move T from A along AX. The point Q now describes a tractrix OF with AX as asymptote. On doing the same from the end-position BA we get a second tractrix, BH, also with AX as asymptote.

If we now take on AX a suitable point R and draw with this point as centre and TQ as radius an arc ED between these two tractrices, we can consider the curve DOSBED as the Q-curve. We need only start at the position DR for QT, move T to A, then round the curve and back to R, turning QT at last about R till Q comes back to D.

If R has been well selected the arc ED will cut the curve OSB, and therefore the area of the Q-curve will be partly positive, partly negative. If, in fig. 16, the point R is moved higher up, the positive part will increase; on moving it lower down, the negative. Hence there must exist a definite position for R such that the area (Q) vanishes.

This shows the *possibility* of using the simple 'Hatchet' as a planimeter; but it is not yet a practical instrument. The above shows only :—

If a point A, a line AX, and an initial position OA are taken arbitrarily, then a point R exists on AX such that on starting with T at R and Q at D we get the area reduced to twice the area of a sector with radius QT.

We have here at our disposal first the point A on the curve; secondly, the direction of the line AX; thirdly, the initial direction of QT, for it comes to the same whether we take OA or DR as given. These three being fixed, the above proves the existence of a point R. The change of one of these three quantities alters the position of R.

We must, in order to get a practically useful rule for determining R, restrict the superabundance of choice which the above theory leaves us. A perfectly satisfactory rule has not yet been found. The only generally usable one is that given by the inventor.

As the Hatchet Planimeter has during the last few years excited some interest both in England and abroad, and as I have heard its invention attributed to various men, the following historical facts may be mentioned.

I became acquainted with it early in 1893 through Professor Greenhill, and ordered one from the maker, Herr Cornelius Knudsen, in Copenhagen. With it I received a pamphlet in French dated 1887. It contains an analytical theory without mentioning Captain Prytz. After my showing the instrument at the Physical Society and mentioning that a complete theory did not yet exist, there appeared in 'Engineering' a paper by Macfarlane Gray. In consequence of this Captain Prytz contributed his investigations to the same journal (where his name is changed to Pryty). It is practically an English translation of the pamphlet mentioned. I have since seen a new pamphlet with the name of Captain Prytz on it. In England the instrument seems, however, to have first become known through Mr. Druitt Halpin, who mentioned it to Professor Unwin, Professor Goodman, and other engineers about 1889. Professor Goodman exhibited a somewhat improved form early this year at the Institution of Civil Engineers.

He has given the rod between the knife-edge and the tracer the shape of a circular arc, radius l, and engraved a scale on it, so that it is possible to measure the arc between the two marks made on the paper instead of the chord.

Quite recently (October) I have learnt from Coradi that in December 1893 F. Hohmann communicated the idea of such a planimeter to him, and also that Professor Ljubomir Kleritj, of Belgrad, had invented a new planimeter. This is only a modification of Prytz's. In it the knife-edge is replaced by a knife-edge wheel, whilst the other end rests on two feet between which the tracer is so placed that its point is just off the paper. These feet are fastened to a cross-bar which is movable about a point above the tracer. The instrument thus rests firmly on three points. Both Professor Unwin and Coradi have pointed out to me that it would be an improvement if to Prytz's form a disc be added as a handle which can turn freely about the tracer. Kleritj's form supplies this.

Just now I have received a reprint from a Servian journal in which Professor Szily, of Budapest, has, at the request of Kleritj, developed the equation to the path of the knife-edge when the tracer moves along the circumference of a circle. It is dated December 1893. But it does not seem to advance the curiously interesting theory of the instrument.

The geometrical considerations given above were started by me and more fully worked out by Mr. A. Sharp, who has obtained several other results, which, however, do not yet yield any better practical rules than those given by Prytz.

LINKAGE INTEGRATORS.

J. Amsler ('Vierteljahrsschrift,' 1856, p. 29) describes what he calls a 'Flächenreductor' (area-reducer), and in connection with this he gives a theorem about pantographs which deserves notice.

Starting with the fundamental theorem about the generation of an area by a line of finite length, these theorems are easily obtained.

If we denote by (AB) the area swept over by the line AB during a cyclical motion, by (P) the areas enclosed by the close path of a point P, then we have

$$(AB)=(B)-(A)+n\pi AB^2$$

If $n=0$, and this case alone we shall follow up, we have

$$(AB)=(B)-(A)$$

If we take a third point C on, or off, the line AB, we always have

$$(AB)=(B)-(A),\ (BC)=(C)-(B),\ (CA)=(A)-(C)$$

These give at once

$$(AB)+(BC)+(CA)=0 \text{ and } (AB)=(AC)+(CB)$$

where account always must be taken of the sense, viz., it is

$$AB=-BA \text{ and } (AB)=-(BA)$$

We also have, if a recording wheel be fixed on the line AB whose roll for a complete circuit is w,

$$(AB)=AB\,.\,w,\ (BC)=BC\,.\,w,\ \&c.$$

Hence, if a line performs a cyclical motion without turning completely round, then the area swept over by any segment on the line is proportional to the length of the segment.

Let now A, B, P be points in a straight line and $AB=a$, $AP=p$, $\therefore PB=a-p$; then is

$$(AB)=aw=(B)-(A),\ (AP)=pw=(P)-(A)$$

On eliminating w we get

$$p\,(B)-a\,(P)=(p-a)\,(A), \text{ or } (a-p)\,(A)=a\,(P)-p\,(B)$$

This is Holditch's Theorem.

From this it follows that we can always find one point P in the line AB which describes a curve of zero-area. For it

$$(p-a)\,(A)=p\,(B)$$

$$\therefore\ p=\frac{(A)}{(A)-(B)}a$$

This point shall be called the zero-point in the line.

If $(A)=(B)$, then is $p=\infty$, and the zero-point is at infinity.

For any other point P (not at infinity) we have now

$$a\,(P)=a\,(A),\ \therefore\ (P)=(A)$$

If two points in a line describe closed curves of equal area, all points in the line do the same.

The area enclosed by any point in the line encloses always an area which is proportional to its distance from the zero-point.

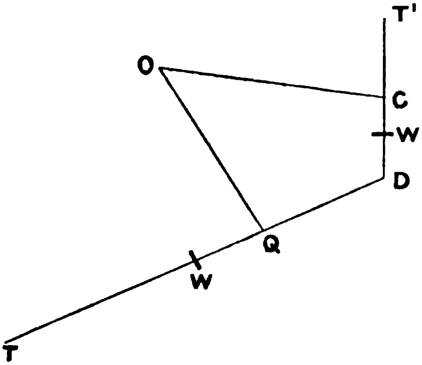
In Amsler's planimeter, or any planimeter of Type I., the point Q is the zero-point of the 'rod' QT.

Let on this rod a point T′ be taken so that $QT=kQT'$; then, whilst T′ is guided along the boundary of an area (T′), the point T will describe a closed curve of k times the area (T′).

J. Amsler proposed (*l.c.*, p. 29, 1856) to have a tube inserted at T′ perpendicular to the paper. At the bottom this carries near the paper a glass plate with a small circular mark, and at the top a lens. The point T is now moved so that the mark at T′ follows the small curve. The point T describes a closed curve whose area is registered by the wheel in square inches, say. The area (T′) is therefore registered k times to the same scale. We have thus a planimeter which registers a magnified area, and is suitable to measure small areas. The advantage is this. In guiding a tracer round a curve the motion of the tracer will be more or less jerky. These jerks at T will be reduced at T′.

This arrangement, however, has one drawback. The figures described by T and T′ are not similar, and this makes it difficult to guide T so that T′ follows a given curve. But this can be overcome as follows: Let us consider a linkage as in fig. 17. OQT is an ordinary planimeter with the pole at O. TQ is produced to D, and the extra bars OC, CD are added, with hinged joints. If T describes a closed curve, D will do the same, whilst Q and C are zero-points, provided that QT does not complete a revolution. Let there be registering wheels on TQ and CD, and let their 'rolls' during a circuit described by T be w and w'; then is

FIG. 17.



$$(T)=QT\,.\,w, \qquad (D)=QD\,.\,w=CD\,.\,w'$$

From which, on eliminating w, we get

$$(T)=\frac{QT}{QD}\,.\,CD\,.\,w'$$

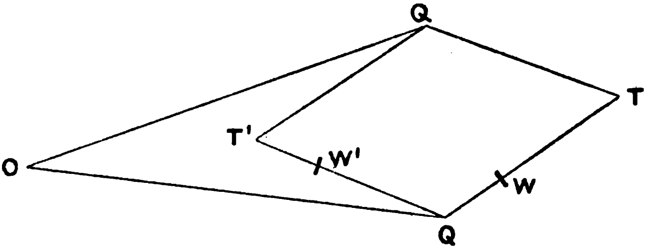
Hence the area (T) can also be measured by the roll of W′.

Similarly, if DC be produced to T′, the area of T′ will be measured either by W′ or by W.

If OQDC be made a parallelogram and T, O, T′ are taken in a line, then T and T′ will describe similar figures.

On this principle the firm Amsler-Laffon has recently constructed a planimeter for measuring small areas. For convenience of construction the points T and T′ are made to describe figures which are only approximately similar, but sufficiently to make it easy to guide the tracer T so that T′ describes a given small curve.

FIG. 18.



It seems to me that we have here a new principle for making integrators which might be called *linkage integrators*; viz., if we take a linkage and move one point T along a given curve, then any other point T′ will describe another closed curve whose area is dependent on that of the given curve.

As a simple example, take a Peaucillier cell with fixed pole O (fig. 18). Give QT a wheel W and QT′ a wheel W′. We have now two planimeters, OQT and OQT′. If $OT=r$, $OT'=r'$, then we have always $rr'=k^2$, where $k^2=OQ^2-QT^2$.

If T describes a closed curve, T′ describes another, and

$$(T)=aw,\ (T')=aw',\ \text{where } QT=a$$

Also $(T)=\frac{1}{2}\int r^2d\theta$ if θ is the angle which OT makes with a fixed line, and

$$(T')=\tfrac{1}{2}\int r'^2d\theta=\frac{k^4}{2}\int\frac{d\theta}{r^2}$$

Hence, as T describes a closed curve, T′ describes another whose area is proportional to $\int\frac{d\theta}{r^2}$.

If dS denotes an element of the area (T), the last integral becomes by Stokes' Theorem about the conversion of a line- into a surface-integral

$$\frac{k^4}{2}\int\frac{d\theta}{r^2}=k^4\iint\frac{dS}{r^4}$$

Hence

$$(T')=k^4\iint\frac{dS}{r^4},\ \text{which is measured by } w'$$

The origin must be outside the area (T) to avoid $r=0$.

On Methods that have been adopted for Measuring Pressures in the Bores of Guns. By Captain Sir A. Noble, *K.C.B., F.R.S., M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso.*]

The importance of ascertaining, with some approach to accuracy, the pressures which are developed at various points along the bores of guns by gunpowder or other propelling agent is so great that a variety of means have been proposed for their determination, and I purpose, in this paper, to give a very brief account of some of these means, pointing out at the same time certain difficulties which have been experienced in their employment, and the errors to which these methods have been in many cases subject.

The earliest attempt, by direct experiment, to ascertain pressures developed by fired gunpowder was that made by Count Rumford in his endeavour to determine the pressures due to different densities of charge. He assumed, the principles of thermodynamics being then unknown, that charges fired in a small closed gun-barrel would give pressures identical with those given by charges doing work both on the projectile and on the products of combustion themselves; but even this error was a small one compared with that which led him to adopt, as correct, his extravagant estimate of the pressures developed.

For a density of unity—or, in other words, for a charge approximately filling a chamber in which it was fired—he estimated the pressure at over 101,000 atmospheres, or at 662 tons per square inch.

He adopted this pressure notwithstanding the great discrepancy which he found to exist between the two series of experiments which he made, and he meets the objection that, were the pressure anything approaching that which he gives, no gun that ever was made would have a chance of standing by assuming that the combustion of powder is exceedingly slow, and lasts the whole time occupied by the projectile in passing through the bore.

It is sufficiently curious that a man so eminent for his scientific attainments as was Rumford should have fallen into so great an error, both because any attempt at calculation would have shown him his mistake, and because Robins, sixty years earlier, had conclusively proved that with the small grain powders then used—and it must be remembered that Rumford's powder was sporting of very fine grain—the whole of the powder was fired before the bullet was very greatly removed from its seat. Robins's argument—and it is incontrovertible—was, that were it otherwise a much greater energy would be realised from the powder when the weight of the projectile was doubled, trebled, quadrupled, &c.; but his experiments showed that under these circumstances the work done by the powder was nearly the same.

For other objects, on a much larger scale, and with appliances far superior to those which the great man I have named had at his disposal, I have had occasion to repeat Robins's experiment, and the results are interesting. With a charge of 10 lb. of the powder known as R.L.G2 and a shot weighing 30 lb. a velocity of 2,126 f.s., representing an energy of 971·6 foot-tons, was attained. The same charge being used, but the weight of the projectile being doubled, the velocity was reduced to 1,641 f.s., while the energy was increased to 1,125 foot-tons. With a shot weighing 120 lb. the velocity was 1,209 f.s. and the energy 1,196 foot-tons. With a shot of 150 lb. the velocity was 1,080 f.s. and the energy 1191·5 foot-tons; while with a shot of 360 lb. the velocity was reduced to 691 f.s., representing a muzzle energy of 1,191·9 foot-tons. These energies were obtained with maximum chamber pressures respectively of 13·5 tons, of 17·25 tons, of 19 tons, of 20 tons, and of 22 tons per square inch. It will be noted that the maximum energy obtained was realised with the shot of 120 lb. weight, the energy given by a shot of 360 lb.—*i.e.* three times that weight, or twelve times the weight of the original shot—being nearly exactly the same.

Very different, however, were the results when one of the modern powders, introduced with the special object of insuring slow combustion, was compared with the R.L.G2 experiments which I have just quoted.

With brown prismatic or cocoa powder an exactly similar series was fired. The 30-lb. shot gave a velocity of 1,515 f.s. and an energy of 493·4 foot-tons; the 60-lb. shot gave 1,291 f.s., and an energy of 693·4 foot-tons; the 120-lb. shot, 1,040 f.s., and 877·5 foot-tons; the 150-lb. shot, 948 f.s. and 920·7 foot-tons; while with the heaviest shot, the 360 lb., the velocity attained was 654 f.s., equivalent to an energy of 1,064·7 foot-tons. The maximum chamber pressures in this series varied from 4·8 tons per square inch, with the lightest projectile, to 9·6 with the heaviest; and with this powder it will be observed that the energy developed increased steadily and considerably with each increment in the weight of the shot, while the low chamber pressure shows that, even with the heaviest shot, the projectile must have moved a considerable distance from its seat before the charge can be considered to have been entirely consumed.

I have mentioned the discrepancy between Rumford's two series of experiments. This discrepancy was very great, the one series giving, for a density of unity, a tension of about 190 tons per square inch, or 29,000 atmospheres, the other series giving a tension of over 101,000 atmospheres. It is remarkable that Rumford makes no attempt to explain this discrepancy, but, as he deliberately adopts the higher tension, it is not improbable that he was led to this conclusion by an erroneous estimate of the elastic force of the aqueous vapour contained in the powder or formed by its explosion. He considered, relying on M. de Betancourt's experiments, that the elasticity of steam is doubled by every addition of temperature equal to 30° F., and his only difficulty appears to have been—he expressly leaves to posterity the solution of the problem—why the tension of fired gunpowder is not much higher than even the enormous pressure which his experiments appeared to indicate.

It will be remembered that Rumford's apparatus consisted of a small but strong wrought-iron barrel, terminated at one end by a small closed vent, so arranged that the charge could be fired by the application of a red-hot ball. At the other end it was closed by a hemisphere upon which any required weight could be placed. His method was as follows:—A given charge being placed in the bore, a weight judged to be equivalent to the expected gaseous pressure was applied. If the weight were lifted, it was increased until it was just sufficient to confine the gases, and the pressure was then assumed to be that represented by the weight.

It seems probable that Rumford's erroneous determinations were mainly due to two causes:—

1st. To the weight closing the barrel being lifted, not by the mere gaseous pressure, but by the products of explosion (produced, it will be remembered, from a very 'brisante' powder and considerably heated by the red-hot ball) being projected at a high velocity against it. In such a case the energy acquired in traversing the barrel would add notably to the pressure due to the density of the charge; and it is again remarkable that the augmentation of pressure, due to this cause, was clearly indicated by an experiment designed for the purpose by Robins.

2nd. To the gases acting on a much larger area than was allowed for in his calculations; and this view appears to be confirmed by the *résumé* he gives of his experiments.

No attempt was made for very many years either to corroborate or amend Count Rumford's determinations; but, in 1845, General Cavalli endeavoured indirectly to arrive at the pressure developed by different kinds of powder in a gun of 16 cm. calibre. His method consisted in drilling holes in the gun at right angles to the axis, at different distances from the base of the bore, in which holes were screwed small barrels of wrought iron, so arranged as to throw a bullet which would be acted on by the charge of the gun while giving motion to the projectile. By ascertaining the velocities of these bullets he considered that the theoretical thickness of the metal at various points along the bore could be deduced. His experiments led him to some singular results.

He believed that with some very *brisante* Belgian powder with which he experimented a chamber pressure of 24,022 atmospheres (157·6 tons per square inch) had actually been reached, while with an ordinary powder and a realised energy of nearly the same amount the maximum chamber pressure was only 3,734 atmospheres (24·5 tons per square inch). With the brisante powder this erroneous conclusion was doubtless due to two principal causes, viz.—

1st. To the seat of the small bullet being at a considerable distance from the charge. Under these circumstances, as later on I shall have occasion to describe experiments to prove, a far higher pressure induces motion in the bullet than is due to the tension of the gases in a state of rest.

2nd. To the brisante nature of the powder. With such powders, especially in large charges, it has been proved that great variations of pressure exist in the powder chamber itself, in some cases the pressure indicated at one point of the chamber being more than double that at others.

It has further been proved that with brisante powders waves of pressure of great violence sweep from one end of the chamber to the other, and if Cavalli's small bullet were acted on by one of these waves an exceedingly high pressure would, without doubt, be indicated.

3rd. A third cause of error, but much slighter, is due to the muzzle pressure, when the small bullet quits its barrel, being both abnormally high and also abnormally sustained; hence there will be a considerable increment of velocity after the bullet quits the gun.

It is but fair to add that the results obtained by Cavalli with the powders which he terms 'inoffensive' are, if some correction be made for the third cause of error alluded to above, not far removed from the truth.

A Prussian Artillery Committee, under the presidency of General Neumann, made, in 1854, a great improvement on the plan proposed and employed by Cavalli.

Their mode of procedure consisted in drilling a hole in the powder chamber of the gun to be experimented with, in which hole was placed a small barrel of about six inches in length. Now, when the gun was loaded, if in the small barrel were placed a cylinder of a length equal to that of the projectile, it is clear that, on the assumption that the pressure in the powder chamber is uniform, the cylinder and the projectile will describe equal spaces in equal times; hence, if we determine the velocity of the cylinder when it quits the small barrel, we know the velocity of the projectile when it has moved six inches from its seat. By altering the length of the column of the cylinder placed in the small barrel, and ascertaining the resultant velocity, the velocity of the projectile at any desired point of the bore can be determined.

General Neumann's Committee carried out their experiments only in very small guns and with the grained powder used in those days. Their results were probably not far from the truth, although subject to one of the defects to which I alluded in reviewing General Cavalli's experiments. Indeed, these results were examined and entirely confirmed by the distinguished Russian artillerist General Mayevski, in a very elaborate memoir; but the experiments of the Prussian Committee were chiefly remarkable for being, so far as I know, the first to recognise the variations of pressure which may exist in the powder chamber itself, variations which may, under certain circumstances, attain great magnitude, and to which I have already drawn attention.

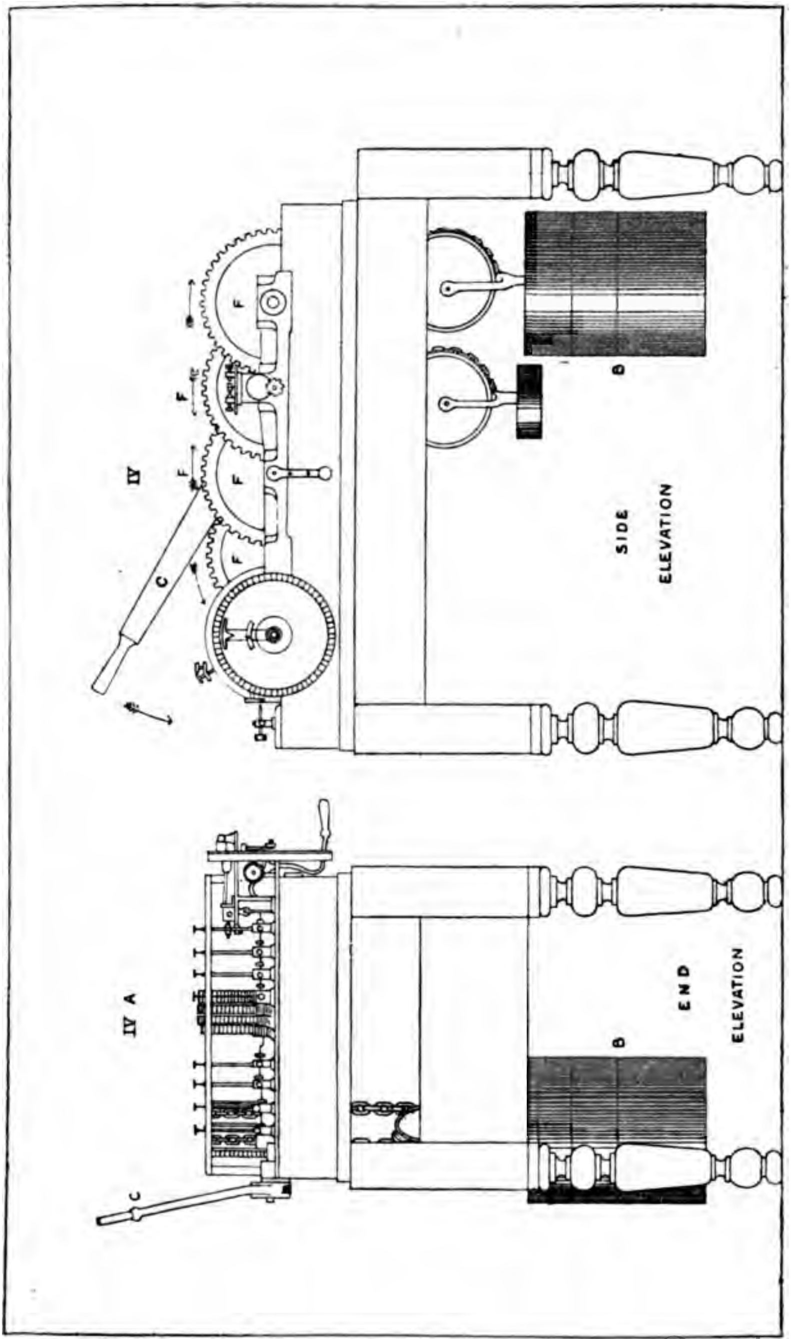
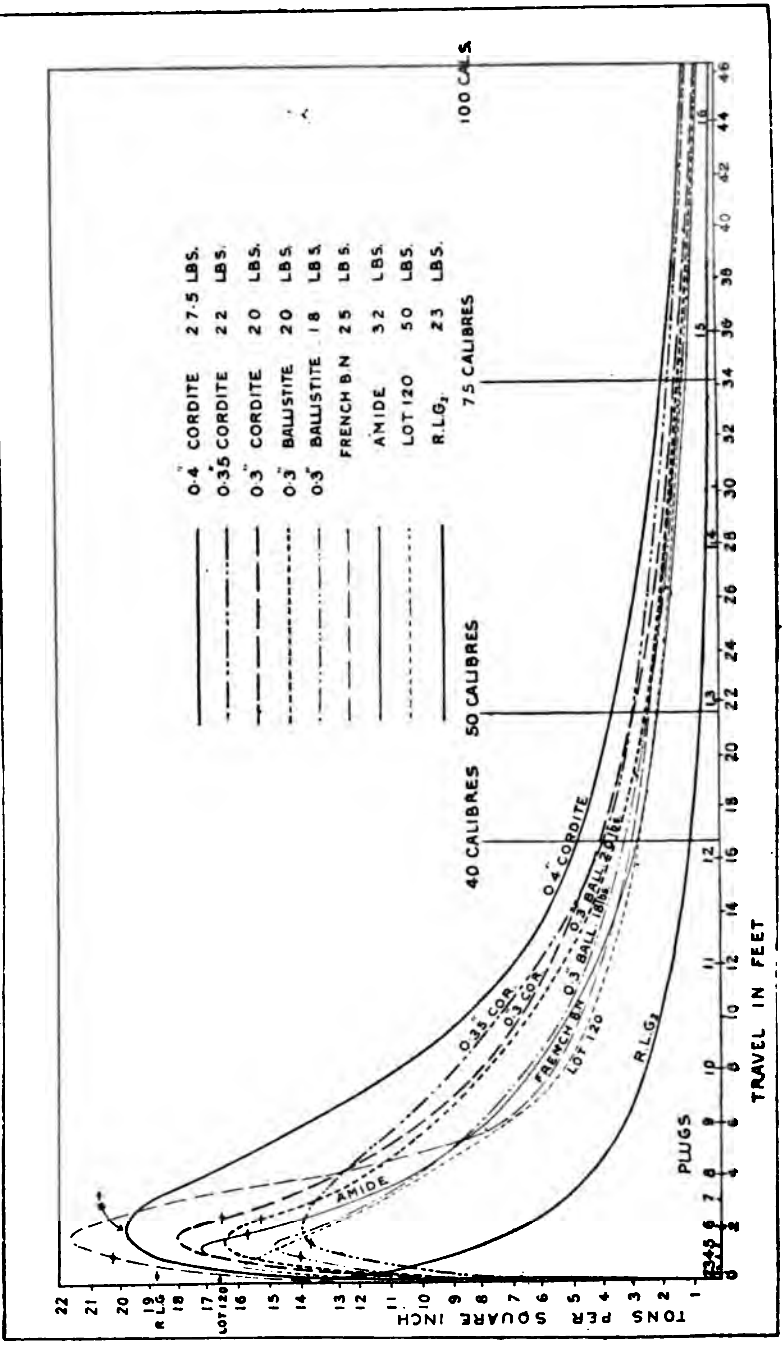


FIG. 4.—Chronoscope Elevation.

FIG. 10.—Chronoscope Pressure Curves, 100-calibre 6-inch Gun.

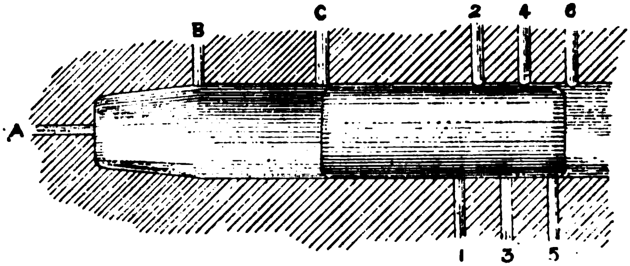


chamber in the same experiment. The pressures, moreover, are often greatly above those which would exist were the charge absolutely confined in a close vessel.

A very striking instance may be cited from the early experiments of the Explosive Committee with a M.L. 10-inch gun (fig. 8). The first round was fired with a charge of 87½ lb. Belgian Pebble, the charge being lighted in two places. The maximum pressure with the chronoscope was 25·2 tons. With the crusher gauge the pressure in the chamber varied from 22·2 to 24·8 tons per square inch, while the energy developed by the powder on the shot was 6,240 foot-tons. With the second round, all conditions being the same except that the charge was fired at a single point, the chronoscope pressure was as nearly as possible the same; but the chamber pressure was, at the rear, 79·1 tons; in the middle 52·0 tons; at the seat of the shot 39·5 and 48·0 tons per square inch. A similar large excess of pressure was shown at points 1 foot and 2 feet in advance of the seat of the shot, and the crusher gauges did not show their normal pressures until points 5 or 6 feet from the seat of the shot had been reached.

Yet with the violent difference in pressure shown between the crusher gauges in this round and in the previous round (which I have just cited), the difference of energy developed in the shot was exceedingly trifling, being only 6,249 foot-tons, as against 6,240.

FIG. 8.—Position of Pressure Plugs in 10-inch Gun.



I believe I have expressed pretty clearly my views that crusher gauges placed in the chase are for absolute determination not of much value, and their main use, if used at all, is to give comparative results. But the same remark does not apply to crusher gauges placed in the chamber.

Gases moving at a high velocity in the chase are, so to speak, performing their proper function; but the same is not true of those violent waves of pressure in the chamber which appear to accompany the explosion of all brisante powders, and which occur either when the projectile has hardly moved at all or when it is moving with a comparatively slow velocity.

It is our object, and in this we have had great success, to avoid these waves as much as possible; and in attaining this end our indebtedness to the crusher gauge is very great, as this instrument has made plain to us not only the extreme violence but the variability of these oscillations.

I have heard it urged that these waves of pressure are, after all, not of high importance, because their maxima act at the same time only upon a very small section of the bore, and the continuity of the metal is amply sufficient to resist the stress.

This is no doubt true, but it is not true of the base of the bore, which in modern guns is almost invariably a movable piece, and which under certain circumstances might have to sustain the full force of the violent pressures, a sample of which I have cited.

To ascertain the mean pressure throughout the bore it seems to me that there is no method so satisfactory, despite its attendant labour, as that of making the projectile write its own story. In that case we cannot fall into the error of making the pressures three or four times as great as are necessary to generate the energy the projectile has actually acquired, while occasional errors, due to causes I have not time to explain, are easily detected and eliminated.

To give an idea of how great is the range of velocity over which these experiments have been carried, I exhibit here diagrams (figs. 9 and 10) showing the velocities and pressures obtained with several of the new explosives which in recent years have attracted so much attention. Observe also how closely, with the exception of the one somewhat brisante powder, the results given by the chronoscope accord with those given by the crusher gauge. Where these differ, as I have elsewhere pointed out, the two modes of research so widely different are complementary to each other.

The chronoscope takes little or no note of the violent oscillations of pressure acting during exceedingly minute intervals of time. On the other hand, if with the explosives I allude to we trusted to the indications of the crusher gauge, we should arrive at a most erroneous idea of the energy communicated to the projectile.

In concluding, if I may venture to quote the excuse of a much more eminent man than myself, I have only to express my regret that I have not had time to condense the remarks with which I fear I have fatigued you, while at the same time I am aware that there are many important points in connection with my subject which I have left altogether untouched, and others upon which I have touched that require further elucidation.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCE.

PRESIDENT OF THE SECTION—Professor A. W. RÜCKER, M.A., F.R.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

IT is impossible for a body of English scientific men to meet in one of our ancient university towns without contrasting the old ideal of the pursuit of learning for its own sake with the modern conception of the organisation of science as part of a pushing business concern.

We are, as a nation, convinced that education is essential to national success. Our modern universities are within earshot of the whirr of the cotton-mill or the roar of Piccadilly. Oxford and Cambridge themselves are not content to be centres of attraction to which scholars gravitate. They have devised schemes by which their influence is directly exerted on every market town and almost on every village in the country. University extension is but a part of the extraordinary multiplication of the machinery of education which is going on all around us. The British Association, which was once regarded as bringing light into dark places, is now welcomed in every large provincial town by a group of well-known men of science; and we find ready for the meetings of our Sections, not only the chapels and concert-rooms which have so often and so kindly been placed at our disposal, but all the appliances of well-designed lecture-rooms and laboratories.

I do not propose, however, to detain you this morning with a discourse on the spread of scientific education, but you will forgive me if I illustrate its progress by two facts, not perhaps the most striking which could be selected, but especially appropriate to our place of meeting. It is little more than thirty years since the two branches of science with which our Section deals, Mathematics and Physics, have been generally recognised as wide enough to require more than one teacher to cope with them in an educational institution of high pretensions and achievement. In 1860 the authorities of the Owens College, Manchester, debated whether it was desirable to create a Professorship of Natural Philosophy in addition to, and independent of, the Chair of Mathematics. It was thought necessary to obtain external support for the opinions of those who advocated this step. An appeal was made to Professors De Morgan and Stokes. The former reported that a 'course of experimental physics is in itself desirable;' the latter, that 'there would be work enough in a large institution for a mathematician and a physicist.'

In the end the Chair of Natural Philosophy was established, and the fact that our host of to-day, Professor Clifton, was its first occupant reminds us how little we have advanced in time and how far in educational development from the days when propositions such as those I have cited were only accepted on the authority of the names of Stokes and De Morgan.

The other fact to which I would refer is that the Clarendon Laboratory, in which the meetings of Section A are to be held, though erected barely a quarter of a century ago, was the first laboratory in this country which was specially built and designed for the study of experimental physics. It has served as a type. Clerk Maxwell visited it while planning the Cavendish Laboratory, and traces of Professor Clifton's designs can be detected in several of our university colleges.

But though our surroundings remind us of the improvement which has been effected in the equipment of our science, it would not be difficult to indicate weak points which should forthwith be strengthened. On these, in so far as they affect education, I will not dwell—and that for two reasons. In the first place, we meet to-day not as teachers, but as students; and, secondly, I think that whereas we have as a nation awoke—though late in the day—to the importance of education, we are not yet fully awake to the importance of learning. Our attitude in such matters was exactly expressed by one of the most eminent of the witnesses who gave evidence before the 'Gresham Commission.' In his opinion the advancement of knowledge must in a university in London be secondary to the higher instruction of the youth of London. If this be so—and I will not now dispute it—we shall surely all agree that somewhere or other, in London or out of it, included in our universities or separate from them, there ought to be institutions in which the advancement of knowledge is regarded as of primary and fundamental interest, and not as a mere secondary by-product thrown off in the course of more important operations.

It is not essential that in such an institution research should be the only task. Investigation may be combined with the routine work of an observatory, with teaching, with the care of standards, or with other similar duties. It is, however, essential that, if the advancement of knowledge is seriously regarded as an end worth attaining, it should not be relegated to a secondary place.

Time and opportunity must be found for investigation, as time and opportunity are found for other tasks. It is not enough to refer to research in a prospectus and then to leave it to be accomplished at odd times and in spare moments not claimed by more urgent demands. Those to whom the future of the higher learning in England is dear must plan and scheme to promote the life-long studies of men, as in the last quarter of a century they have struggled, with marked success, to promote the preparatory studies of boys and girls. That the assignment of a secondary position to research is the more popular view, and that the necessity for encouraging it has as yet hardly been grasped by many of those who control our modern educational movements is, I fear, too true. It is therefore a matter for congratulation that within the last year Oxford has established a research degree, and has thus taken an important step towards gathering within her fold workers of mature years who are able and willing, not merely to gain knowledge, but to add to it.

We may also note, with pleasure and gratitude, that the stream of private munificence has recently been in part directed to the advancement of learning. Sir Henry Thompson has generously offered a sum of 5,000*l.* to provide a large photographic telescope for the National Observatory at Greenwich. The new instrument is to be of 26 inches aperture and 22 feet 6 inches focal length, or exactly double the linear dimensions of that which has been previously employed. Mr. Ludwig Mond, too, has added to his noble gifts to science by the new research laboratories which he is about to establish in connection with the Royal Institution. Albemarle Street is thronged with memories of great discoveries. The researches of Lord Rayleigh and the remarkable results of Professor Dewar's studies of matter at low temperatures are maintaining the great reputation which the Royal Institution has gained in the past, and all English physicists will rejoice that prospects of new and extended usefulness are opening before it.

Another hopeful, though very embarrassing, fact is that the growth in the number of scientific workers makes it increasingly difficult to find the funds which are necessary for the publication of their work. Up to the present the author of a paper has had to submit it to criticism, but, when it has been approved by competent judges, it has been published without ado and without expense to himself. This is as it should be. It is right that due care should be exercised to prune away all unnecessary matter, to reduce as far as may be the necessary cost. It will, however, be a great misfortune if judgment as to what curtailment is necessary is in future passed, not with the object of removing what is really superfluous, but in obedience to the iron rule of poverty. Apart from all other disadvantages, such a course would add to the barriers which are dividing the students of different sciences. A few lines and a rough diagram may suffice to show to experts what has been attempted and what achieved, but there is no paper so difficult to master as that which assumes that the reader starts from the point of vantage which months or years of study have enabled the author to attain. Undue pruning will not make the tree of knowledge more fruitful, and will certainly make it harder to climb.

Connected also with the vast increase of scientific literature is a growing necessity for the publication of volumes of abstracts, in which the main results of recent investigations are presented in a concentrated form. English chemists have long been supplied with these by the Chemical Society. The Physical Society, though far less wealthy than its elder sister, has determined to undertake a similar task. We are compelled to begin cautiously, but in January next the first number of a monthly pamphlet will be issued containing abstracts of all the papers which appear in the principal foreign journals of Physics. In this venture the Society will incur grave responsibilities, and I avail myself of this opportunity to appeal to all British physicists to support us in a work, the scope of which will be rapidly extended if our first efforts succeed.

From this brief glance at what has been or is about to be done to promote the study of Physics, I must now turn to the discussion of narrower but more definite problems, and I presume that I shall be most likely to deserve your attention if I select a subject in which I am myself especially interested.

During the last ten years my friend Dr. Thorpe and I have been engaged upon a minute magnetic survey of the United Kingdom. The main conclusions at which we have arrived are about to be published, and I do not propose to recount them now. It is, however, impossible to give so long a time to a single research without having one's attention drawn to a number of points which require further investigation, and I shall perhaps be making the best use of this opportunity if I bring to your notice some matters in the practical and theoretical study of terrestrial magnetism which deserve a fuller consideration than has yet been given to them.

In the first place, then, there is little doubt that the instruments at present used for measuring Declination and Horizontal Force are affected with errors far greater than the error of observation.

We employed four magnetometers by Elliott Brothers, which were frequently compared with the standard instrument at Kew. These measurements proved that the instrumental differences which affect the accuracy of the declination and horizontal force measurements are from five to ten times as great as the error of a single field observation. The dip circle which two generations ago was so untrustworthy is, in our experience, the most satisfactory of the absolute instruments.

In most cases these comparisons extended over several days, but the Astronomer Royal has described in his recent report observations made at Greenwich for two years and a half with two horizontal force instruments. These differ between themselves, and the discrepancy is of the same order of magnitude as those we have detected.

If such differences exist between instruments of the Kew pattern, it is probable that they will be still greater when the magnetometers under investigation are of different types.

This point has been investigated by Dr. Van Rijckevorsel, who five years ago visited Kew, Parc St. Maur, Wilhelmshaven, and Utrecht, and, using his own instruments at each place, compared the values of the magnetic elements determined by himself with those deduced from the self-registering apparatus of the observatory.

The discrepancies between the so-called standards, which were thus brought to light, were quite startling, and prove the necessity for an investigation as to their causes.

Magneticians had long been aware that the instruments used by travellers should be compared at the beginning and end of a journey with those at some fixed observatory, to make sure that the comparatively rough usage to which they are subjected has not affected their indications. But Dr. Van Rijckevorsel's expedition first drew general attention to the fact that there are serious differences between the standard observatory instruments themselves.

The importance of a careful comparison between them was at once recognised. The Magnetic Sub-Committee of the International Meteorological Conference, held at Munich in the autumn of 1891, resolved that it is 'necessary that the instruments employed for absolute measurements at the different observatories should be compared with each other and the results published.' As far as I am aware, nothing has been done to give effect to this resolution, but the necessity for such an international comparison is urgent. The last few years have been a period of unexampled activity in the conduct of local magnetic surveys. To cite instances from the north-west of Europe only, observations have recently been made on a more or less extended scale in the United Kingdom, France, Holland, North Germany, and Denmark.

It will be absurd if these surveys cannot be collated and welded into a homogeneous whole, because we are in doubt whether the indications of our standard instruments for the measurement of declination and dip differ by five or six minutes of arc.

If, however, an official international comparison of the magnetic standards in use in different countries is instituted, it is probable that only one observatory in each country will take part in it.

It may fairly be left to each nation to determine for itself the relations between the results of measurements made in its own institutions. Apart, therefore, from all other reasons, we in England would only be able to make the best use of an international comparison if we had beforehand set our own house in order, and were able at once to extend the results of experiments made at Kew or Greenwich to Stonyhurst, Valentia, and Falmouth.

This we are not at the present moment in a position to do. As far as I know, nobody has ever carried a magnetometer backwards and forwards between Kew and Greenwich to test the concordance of the published results. During the recent survey single or double sets of observations have been made at Stonyhurst, Falmouth, and Valentia, with instruments which have been compared with Kew; but these measurements, though amply sufficient for the purposes of our research, were not numerous enough to serve as a firm basis for determining the discrepancies between the various standards, so that the exact relations between these important sets of apparatus are still unknown.

The first point, therefore, to which I wish to draw the attention of the Section is the necessity for a full primary comparison between the standard magnetic instruments in use at our different observatories.

But, if this were satisfactorily accomplished, the question would arise as to whether it should be repeated at regular intervals. We have at present only a presumption in favour of the view that the standards which we know are discordant are nevertheless constant. A single instance may suffice to show how necessary it may be—at all events in the case of outlying and isolated observatories—to put this belief to the test.

In the most recent account of the work of the observatory of the Bombay Government at Colába, the dips are discussed for the period of twenty years between 1872 and 1892. During this interval the adjustment of the agate plates upon which the dip needle rolls has thrice been modified. In 1877 the plates were renewed. In 1881 and 1887 the dip circle was taken to pieces and rebuilt. In the intervals the dip as determined by several needles, but always with this circle, remained approximately constant, but after each overhauling it suddenly altered, increasing by 12′ on the first occasion, by 23′ on the second, and by 20′ on the third. Mr. Chambers states that he 'can give no satisfactory account of this behaviour of the instrument,' but suggests that 'the needle gradually hollows out a depression in the agate plates on which it rolls, and that this characteristic of the dip circle' has not before been discovered owing to the reluctance of magnetic observers to interfere with the adjustments of instruments which are apparently working well.

I do not think that this explanation will suffice. Dr. Thorpe and I employed a new dip circle in the earliest part of our survey work, which has remained in accord with Kew for ten years. During that time the dip has been measured some 700 times with it. This corresponds, I believe, to more than the amount of work done with the circle at Colába in six years, which in turn is longer than some of the intervals in which the Colába instruments gave results erroneous to the extent of 20′. I feel, therefore, quite sure that the difficulties which have been experienced at Bombay are not due to any 'characteristic [defect] of the dip circle.' But, whatever the cause may have been, surely the lesson is that, if such things can happen in so well-known an institution, it is desirable that we should take the moderate pains required to assure ourselves whether smaller—but, possibly, not unimportant—errors are gradually affecting the results at any of our observatories.

This brings me to my next point, namely, that if we are to draw conclusions from the minor differences between measurements of secular or diurnal change made in the observatories, it is not only necessary that we should know whether the instruments are strictly comparable and constant, but the observations must be reduced by precisely the same methods.

In 1886 the late Mr. Whipple drew the attention of the British Association to the fact that there was a systematic difference between the diurnal ranges of declination at Greenwich and Kew. His results were based on the three years 1870–72. In 1890 two of my students, Messrs. Robson and S. W. J. Smith, extended the comparison to three more recent years (1883–6–7), and obtained results in complete accord with those of Mr. Whipple.

It is well known that the average daily oscillation of the magnet is affected by the magnetic weather. Sabine showed that magnetic storms do not merely buffet the needle now in this direction and now in that—they affect its average behaviour, so that the mean swing east and west is different according as we deduce it only from days of magnetic calm or include those of storm.

Mr. Whipple reduced the Kew observations by two methods,[1] one of which depended on the calmest days only, while the other included those which were moderately disturbed. Neither agreed exactly with the method in use at Greenwich, but the difference between the results deduced from them was so small when compared with the difference between either and that obtained at Greenwich, that it seemed possible that the diurnal variations, even at these closely neighbouring places, might differ appreciably. The question whether this is so has now been answered. In 1890, at the request of the Kew Committee, the Astronomer Royal undertook to select early in each year five quiet days in each of the preceding twelve months. It was also agreed that, whether they adopted other methods or not, the chief English magnetic observatories should determine the diurnal variations from these days alone. The Greenwich[2] and Kew observations for 1890 have therefore been worked up in exactly the same way, with the result that the discrepancy, which had persisted for twenty years, has entirely disappeared, and that the two diurnal ranges at the two observatories are in as close accord as could be expected.

If, therefore, we may judge from a single year, the cause of the difference lay in the choice of days. Greenwich will in future give us two diurnal variations—one obtained from the most quiet days only, the other from all days except those of violent storm, and in these we shall have most valuable data for studying the mean effect of disturbances on the diurnal variation.

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[1] Sabine's and Wild's.

[2] The Greenwich observations for subsequent years have not yet been published.

To this satisfactory conclusion I have only one suggestion to add. The Astronomer Royal and M. Mascart now publish for the same stormy days the photographic traces by which the history of a magnetic storm is mapped. Is it possible for Greenwich and Paris also to agree in their choice of calm days for the calculation of the diurnal variation, so that a precise similarity of method may obtain not only between the English observatories, but between England and France?

The importance of co-operation between institutions engaged on the same tasks having been illustrated, I am glad to be able to announce that another step is about to be taken in the same direction. For some years, in spite, I believe, of great financial difficulties, the Cornwall Royal Polytechnic Society has maintained a magnetic observatory at Falmouth. The results of the observations have hitherto been printed in the Journal of the Society only, but the Royal Society has now consented to publish them in the 'Proceedings.' Before long, therefore, the Kew and Falmouth records, which are already worked up in the same way, will be given to the world side by side. Is it too much to hope that this may be the first step towards the production of a British Magnetic Year Book, in which observations whose chief interest lies in their comparison may be so published as to be easily compared?

We owe to private enterprise another advance of the same kind. The managers of the new journal 'Science Progress' have made arrangements with the Kew Committee for the yearly publication of a table showing the mean annual values of the magnetic elements as determined at the various magnetic observatories of the world. It will therefore in future be possible to get a general idea of the rate of secular change in different localities without searching through a number of reports in different languages, which can only be consulted in the rooms of the few societies or institutions to which they are annually sent. The present state of our knowledge of the secular change in the magnetic elements affords indeed very strong support to the arguments I have already adduced in favour of a comparison between the instruments of our magnetic observatories.

The whole question of the cause of this phenomenon has entered on a new stage. It has long been recognised that the earth is not a simple magnet, but that there are in each hemisphere one pole or point at which the dip needle is vertical, and two foci of maximum intensity. A comparison of earlier with later magnetic observations led to the conclusion that one or both of the foci in each hemisphere is in motion, and that to this motion—however caused—the secular change in the values of the magnetic elements is due. Thus the late Professor Balfour Stewart, writing in 1883, says: 'While there is no well-established evidence to show that either the pole of verticity or the centre of force to the North of America has perceptibly changed its place, there is on the other hand very strong evidence to show that we have a change of place on the part of the Siberian focus.'[1] The facts in favour of this conclusion are there discussed. The arguments are based, not on the results of any actual observations near to the focus in question, but on the behaviour of the magnet at points far distant from it in Europe and Asia. The westerly march of the declination needle, which lasted in England up to 1818, and the easterly movement which has since replaced it, are connected with a supposed easterly motion of the Siberian focus, which, it is added, 'there is some reason to believe . . . . has recently been reversed.' In opposition, therefore, to the idea of the rotation of a magnetic focus round the geographical poles which the earlier magneticians adopted, Stewart seems to have regarded the motion of the Siberian focus as oscillatory.

A very different aspect is put upon the matter by a comparison of the magnetic maps of the world prepared by Sabine and Creak for the epochs 1840 and 1880 respectively. Captain Creak, having undertaken to report on the magnetic observations made during the voyage of the 'Challenger,' supplemented them with the unrivalled wealth of recorded facts at the disposal of the Hydrographic Department of the Admiralty. He was thus able, by a comparison with Sabine's map, to trace the general course of the secular changes all over the world for forty years. The negative results may be shortly stated. There is no evidence of any motion either of magnetic pole or focus. The positive conclusions are still more curious. There are certain lines on the surface of the earth towards which in the interval under consideration the north pole of the needle was attracted. From each side the compass veered or backed towards them. Above them the north pole of dip needle moved steadily down.

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[1] *Encyclopædia Brit.*, 9th edition. Art. 'Meteorology—Terrestrial Magnetism.'

There are other lines from which, as tested by compass and dip circle, a north pole was in like manner repelled. The two principal points of increasing attraction are in China and near Cape Horn; the chief points of growing repulsion are in the North of Canada and the Gulf of Guinea.

I am sure that my friend Captain Creak would be the first to urge that we should not generalise too hastily from this mode of presenting the facts, but there can be no doubt that they cannot be explained by any simple theory of a rotating or oscillating pair of poles. *Primâ facie* they suggest that the secular change is due not so much to changes at the principal magnetic points, as to the waxing and waning of the forces apparently exerted by secondary lines or points of attraction or repulsion.

All down the west coast of America, close—be it noted—to one of the great lines of volcanic activity, north hemisphere magnetism has since 1840 been growing in relative importance. Near Cape Horn a weak embryonic pole is developing of the same kind as the well-known pole at the other end of the continent near Hudson's Bay. Along a line which joins Newfoundland to the Cape of Good Hope, precisely the reverse effects have been experienced; while in the Gulf of Guinea a south hemisphere pole is growing within the tropics. Of course I do not suggest that these secondary systems can ever determine the principal phenomena of terrestrial magnetism, or reverse the magnetic states of the hemispheres in which they occur. These are no doubt fixed by the rotation of the earth. I do, however, wish to emphasise the fact that they show that either secular change is due to the conjoint action of local causes, or that if some single agent such as a current system within the earth, or a change of magnetic conditions outside it, be the primary cause, the effects of this cause are modified and complicated by local peculiarities.

Mr. Henry Wilde has succeeded in representing with approximate accuracy the secular change at many points on the surface of the earth by placing two systems of currents within a globe, and imparting to the axis of one of them a motion of rotation about the polar axis of the earth. But he has had to supplement this comparatively simple arrangement by local features. He has coated the seas with thin sheet iron. The ratio between the two currents which serves to depict the secular change near the meridian of Greenwich fails in the West Indies. Thus this ingenious attempt to imitate the secular change by a simple rotation of the magnetic pole supports the view that local peculiarities play a powerful part in modifying the action of a simple first cause, if such exist. I need hardly say that I think the proper attitude of mind on this difficult subject is that of suspended judgment; but there is no doubt that recent investigation has, at all events, definitely raised the question how far secular change is either due to or modified by special magnetic features of different parts of the earth.

It is possible that light may be thrown upon this point by observations on a smaller scale. Assuming for the moment that the difference in the secular changes on opposite sides of the Atlantic is due to a difference of local causes, it is conceivable that similar causes, though less powerful and acting through smaller ranges, might produce similar though less obvious differences between places only a few miles apart. For testing this Greenwich and Kew are in many respects most favourably situated. Nowhere else are two first-class observatories so near together. Differences in the methods of publishing the results have made it somewhat difficult to compare them, but the late Mr. Whipple furnished me with figures for several years which made comparison easy. Without entering into details it may be sufficient to say that the declination needles at the two places do not from year to year run parallel courses. Between 1880–82 Kew outstripped its rival, between

1885 and 1889 it lost, so that the gain was rather more than compensated. The difference of the declination of the two places appears to increase and diminish through a range of five minutes of arc.

This evidence can be supplemented by other equally significant examples. No fact connected with terrestrial magnetism is more certain than that at present the rate of secular change of declination in this part of Europe increases as we go north. This is shown by a comparison of our survey with those of our predecessors fifty and thirty years ago, by M. Moureaux's results in France, and by Captain Creak's collation of previous observations. Yet, in spite of this, Stonyhurst, which is some 200 miles north of Greenwich and Kew, and should therefore outrun them, sometimes lags behind and then makes up for lost time by prodigious bounds. Between 1882 and 1886 the total secular change of declination at Stonyhurst was about 3′·5 less than that at Greenwich and Kew, whereas in the two years 1890–92 it reached at Stonyhurst the enormous amount of 28′, just doubling the corresponding alteration registered in the same time at Kew. If these fluctuations are caused by the instruments or methods of reduction, my argument in favour of frequent comparisons and uniform treatment would be much strengthened; but, apart from the inherent improbability of such large differences being due to the methods of observation, the probability of their physical reality is increased by the work of the magnetic survey.

The large number of observations at our disposal has enabled us to calculate the secular change in a new way, by taking the means of observations made about five years apart at numerous though not identical stations scattered over districts about 150 miles square. The result thus obtained should be free from mere local variations, but as calculated for the south-east of England for the five years 1886–91 it differs by nearly 5′ from the change actually observed at Kew.

We have also determined the secular change at twenty-five stations by double sets of observations made as nearly as possible on the same spot at intervals of several years. The results must be interpreted with caution. In districts such as Scotland, where strong local disturbances are frequent, a change of a few yards in the position of the observer might introduce errors far larger than the fluctuations of secular change. But when all such cases are eliminated, when all allowance is made for the possible inaccuracy of field observations, there are outstanding variations which can hardly be due to anything but a real difference in the rate of change of the magnetic elements.

A single example will suffice. St. Leonards and Tunbridge Wells are about thirty miles apart. Both are situated on the Hastings Sand formation, and on good non-magnetic observing ground. At them, as at the stations immediately around them—Lewes, Eastbourne, Appledore, Etchingham, Heathfield, and Maidstone—the local disturbing forces are very small. All these places lie within a district about forty miles square, at no point of which has the magnet been found to deviate by 5′ from the true magnetic meridian. No region could be more favourably situated for the determination of the secular change, yet according to our observations the alteration in the declination at St. Leonards in six years was practically equal to that at Tunbridge Wells in five. It is difficult to assign so great a variation to an accumulation of errors, and this is only one amongst several instances of the same kind which might be quoted.

We find, then, when we consider the earth as a whole, grave reason to question the old idea of a secular change caused by a magnetic pole or focus pursuing an orderly orbit around the geographical axis of the earth, or oscillating in some regular period in its neighbourhood. It would, of course, be absurd to admit the possibility of change in the tropics and to deny that possibility in the arctic circle, but the new facts lead us to look upon the earth not as magnetically inert, but as itself—at the equator as well as at the pole—producing or profoundly modifying the influences which give rise to secular change. And then, when we push our inquiry further, accumulating experience tells the same tale. The earth seems as it were alive with magnetic forces, be they due to electric currents or to variations in the state of magnetised matter. We need not now consider the sudden jerks which disturb the diurnal sweep of the magnet, which are simultaneous at places far apart, and probably originate in causes outside our globe. But the slower secular change, of which the small part that has been observed has taken centuries to accomplish, is apparently also interfered with by some slower agency the action of which is confined within narrow limits of space. Between Kew, Greenwich, and Stonyhurst, between St. Leonards and Tunbridge Wells, and I may add between Mablethorpe and Lincoln, Enniskillen and Sligo, Charleville and Bantry, the measured differences of secular variation are so large as to suggest that we are dealing not with an unruffled tide of change, which, unaltered by its passage over continent or ocean, sweeps slowly round the earth, but with a current fed by local springs or impeded by local obstacles, furrowed on the surface by billows and eddies, from which the magnetician, if he will but study them, may learn much as to the position and meaning of the deeps and the shallows below. But if this is the view which the facts I have quoted suggest, much remains to be done before it can be finally accepted; and in the first place—to come back to the point from which I started—we want, for some years at all events, a systematic and repeated comparison of the standard instruments in use at the different observatories. That they are not in accord is certain; whether the relations between them are constant or variable is doubtful. If constant, the suggestions I have outlined are probably correct; if variable, then the whole or part of the apparent fluctuations of secular change may be nothing more than the irregular shiftings of inconstant standards.

I cannot myself believe that this is the true explanation; but in any case it is important that the doubt should be set at rest, and that if the apparent fluctuations of secular change are not merely instrumental, the inquiry as to their cause should be undertaken in good earnest.

The question is interesting from another point of view. It is now fully established that even where the surface soil is non-magnetic, and even where geologists have every reason to believe that it lies upon non-magnetic strata of great thickness, there are clearly-defined lines and centres towards which the north-seeking pole of a magnet is attracted, or from which it is repelled. To the magnetic surveyor fluctuations in secular change would appear as variations in the positions of these lines, or as changes in the forces in play in their neighbourhood.

Greenwich and Kew are both under the influence of a widespread local disturbance which culminates near Reading. At both places the needle is deviated to the west of the normal magnetic meridian, and if the westerly declination diminishes sometimes faster and sometimes more slowly at one observatory than at the other, this must be, or, at all events, would in the first instance appear to be, due to local changes in the regional disturbing forces. The questions of the nature of the irregularities of secular change and of the causes of local disturbances are therefore intermingled; and information gained on these points may in turn be useful in solving the more difficult problem of world-wide secular variations.

Two causes of regional and local disturbances have been suggested—viz., earth currents, and the presence of visible or concealed magnetic rocks. The two theories are not mutually exclusive. Both causes of the observed effects may, and probably do, coexist. I have, however, elsewhere explained my reasons for believing that the presence of magnetic matter, magnetised by induction in the earth's field, is the principal cause of the existence of the magnetic ridge-lines and foci of attraction which for so many years we have been carefully tracing. I will only now mention what appears to me to be the final and conclusive argument, which, since it was first enunciated, has been strengthened by the results of our more recent work. We find that every great mass of basic rock, by which the needle is affected at considerable distances, attracts the north-seeking pole. Captain Creak some years ago showed that the same statement is true of those islands in the northern hemisphere which disturb the lines of equal declination, while islands in the southern hemisphere repel the north pole and attract the south. In other words, these disturbances are immediately explained if we suppose that they are due to magnetic matter magnetised by induction. The theory of earth currents would, on the other hand, require that round the masses of visible basalt, and round the island investigated by Captain Creak, currents, or eddies in currents, should circulate in directions which are always the same in the same hemisphere, and always opposed on opposite sides of the equator. For this supposition no satisfactory explanation is forthcoming, and therefore, with all reserves and a full consciousness that in such matters hypothesis differs but little from speculation, it appears to me that the theory that induced magnetism is the main cause of the disturbance has the greater weight of evidence in its favour.

If this be granted, it is evident that the positions of the main lines and centres of attraction would be approximately constant, and, so far as it is possible to form an opinion, these conditions seem to be satisfied. There has certainly been no noticeable change in the chief loci of attraction in the five years which have elapsed between the epochs of our two surveys. Mr. Welsh's observations made in Scotland in 1857-8 fit in well with our own. Such evidence is not, however, inconsistent with minor changes, and it is certain that, as the directions and magnitude of the inducing forces alter, the disturbing induced forces must alter also. But this change would be slow, and as the horizontal force is in these latitudes comparatively weak, the change in the disturbing forces would also be small, unless the vertical force altered greatly. It is, at all events, impossible to attribute to this cause oscillations which occupy at most eight or ten years. It is possible to suggest other changes in the state of the concealed magnetic matter—alterations of pressure, temperature, and the like—to which the oscillations of secular change might be due, but probably there will be a general consensus of opinion that if the slowly changing terms in the disturbance function are due to magnetic matter, the more rapid fluctuations of a few years' period are more likely to be connected with earth currents. It becomes, therefore, a matter of interest to disentangle the two constituents of local disturbances; and there is one question to which I think an answer might be obtained without a greater expenditure than the importance of the investigation warrants. Are the local variations in secular change waves which move from place to place, or are they stationary fluctuations, each of which is confined to a limited area beyond which it never travels? Thus, if the annual decrease in the declination is at one time more rapid at Greenwich than at Kew, and five years afterwards more rapid at Kew than at Greenwich, has the maximum of rapidity passed in the interval through all intervening places, or has there been a dividing line of no change which has separated two districts which have perhaps been the scenes of independent variations? The answer to this question is, I take it, outside the range of our knowledge now; but if the declination could be determined several times annually at each of a limited number of stations in the neighbourhood of London, to this inquiry, at all events, a definite answer would soon be furnished.

There are two other lines of investigation which, I hope, will be taken up sooner or later, for one of which it is doubtful whether the United Kingdom is the best site, while the other is of uncertain issue.

If, however, it be granted that the principal cause of local and regional magnetic disturbances is the magnetisation by the earth's field of magnetic matter concealed below its surface, the question as to the nature of this material still remains to be solved. Is it virgin iron or pure magnetite, or is it merely a magnetic rock of the same nature and properties as the basalts which are found in Skye and Mull? There is, of course, no *à priori* reason why all these different materials should not be active, some in one place and some in another.

As regards the United Kingdom, I have, both in a paper on the Permeability of Magnetic Rocks and in the description of the recent survey, made calculations which tend to prove that, if we suppose that the temperature of the interior of the earth is, at a depth of twelve miles, such as to deprive matter of its magnetic properties, and if we further make the unfavourable assumption that down to that limit the susceptibility is constant, the forces which are observed on the surface are of the same order of magnitude as those which could be produced by large masses of ordinary basalt or gabbro. It would not, however, be wise to generalise this result, and to assume that in all places regional disturbances are due to basic rocks alone.

We know that local effects are produced by iron ore, for the Swedish miners seek for iron with the aid of the magnet, and in some other cases magnetic disturbances of considerable range are so intense as to suggest that material of very high magnetic permeability must be present.

If the concealed magnetic matter were iron, and if it were present in large quantity, it is evident that the results of experiments with the magnetometer and dip circle might be supplemented by observations made with the plumb-line or pendulum. In such a case the region of magnetic disturbance would also be a region of abnormal gravitational attraction. An account of a suggested connection between anomalies of these two kinds occurring in the same district has lately been published by Dr. Fritsche.[1]

Observations made about thirty years ago by a former director of the Astronomical Observatory in Moscow led to the conclusion that throughout two large districts to the north and south of that city the plumb-line is deviated in opposite directions. The deflections from the vertical are very considerable, and indicate a relative defect in the attraction exerted by the rocks in the neighbourhood of Moscow itself, and the suggestion has been made that there is either a huge cavity —a bubble in the earth-crust—a little to the south of the town, or that the matter at that point is less dense than that which underlies the surface strata on either side at a distance of ten or twelve miles.

As long ago as 1853, Captain Meyen made magnetic observations in order to determine whether the same district is also the seat of any magnetic irregularity. His stations were hardly sufficiently numerous to lead to decisive results, but the magnetic elements have recently been measured by Dr. Fritsche at thirty-one places within fifty miles of Moscow. The experiments were all made within eleven days, so that no correction for secular change is required. They indicate a locus of magnetic attraction running through Moscow itself. South of the town the disturbance again changes in direction so as to show either that repulsive forces are in play, or that there is another magnetic ridge line still further to the south. Dr. Fritsche thinks that these observations explain the gravitational anomalies without recourse to the somewhat forced hypothesis of a vast subterranean cave. He assumes that there is a concealed mass of iron, which approaches near to the surface at Moscow, and also along two loci to the south and north of the city. He attributes the magnetic irregularities to the attraction of the central iron hill, the deflections of the plumb-line to the flanking masses. It is perhaps not inconceivable that such results might follow in a special case, but without the support of calculation it certainly appears that the magnetic experiments point to the existence of the principal attracting mass under the town. This is in fact the arrangement shown in the figure with which Dr. Fritsche illustrates his hypothesis. If this is so, the theory would *primâ facie* seem to require that the bob of a plumb-line should be attracted towards and not—as is in some places actually the case—away from the centre of the magnetic disturbance. On the whole, then, though the coexistence of large magnetic and gravitational disturbances in the same place is suggestive, I do not think that they have as yet been proved to be different effects of the same hidden mass of magnetic matter.

In a few weeks an International Geodetic Conference will meet at Innsbruck, at which the Royal Society will be represented. It is, I believe, intended to extend the detailed investigation of the relations between the nature of the earth's crust and the gravitational and magnetic forces to which it gives rise. We may therefore hope that special attention will before long be given to localities where both may combine to give information as to facts outside the range of the ordinary methods of geology.

The second phenomenon on which more light is desirable, is the permanent magnetisation of magnetic rocks. It is known that fragments of these are strongly but irregularly magnetised, but that the effect of very large masses at a distance appears to be due to induced rather than to permanent magnetism. There are three questions to which I should like an answer. Are underground masses of magnetite ever permanently magnetised? Are large areas of surface masses, say a few hundred square yards in extent, ever permanently and approximately uniformly magnetised in the same sense? Is there any relation between the geological age and the direction of the permanent magnetism of magnetic rocks?

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[1] 'Die magnetischen Localabweichungen bei Moskau und ihre Beziehungen zur dortigen Local-Attraction,' *Bulletin de la Société Impér. des Naturalistes de Moscou*, 1894, No. IV.

Inquiries such as these can only be taken up by individual workers, but I venture to think that the comparison of the observatory instruments and the fluctuations of secular change outside the observatories could best be investigated under the auspices of a great scientific society. The co-operation of the authorities of the observatories will no doubt be secured, but it is most important that the comparisons should in all cases be made with one set of instruments, and by the same methods. Whether the British Association, which for so long managed a magnetic observatory, may think that it could usefully inaugurate the work, it would be improper for me in a presidential address to forecast. Who does it is of less importance than that it should be done, and I cannot but hope that the arguments and instances which I have to-day adduced may help to bring about not only the doing of the work, but the doing of it quickly.

The following Papers and Reports were read:—

1. *Preliminary Experiments to find if Subtraction of Water from Air Electrifies it. By* Lord KELVIN, *P.R.S.*, MAGNUS MACLEAN, *M.A., F.R.S.E., and* ALEXANDER GALT, *B.Sc., F.R.S.E.*

Experiments with this object were commenced by one of us in December 1868, but before any decisive result had been obtained, circumstances rendered a postponement of the investigation necessary.

A glass U-tube with vertical branches, each 18 in. long and about 1 in. bore, with the upper eight inches of one of the branches carefully coated outside and inside with clean shellac varnish, was held fixed by an uninsulated support attached to the upper end of this branch. The other branch was filled with little fragments of pumice soaked in strong pure sulphuric acid or in pure water; and a fine platinum wire, with one end touching the pumice, connected it to the insulated electrode of a quadrant electrometer. A metal cylinder, large enough to surround both branches of the U-tube without touching either, was placed so as to guard the tube from electric influences of surrounding bodies (of which the most disturbing is liable to be the woollen cloth sleeves of the experimenters or observers moving in the neighbourhood). This metal tube was kept in metallic connection with the outside metal case of the quadrant electrometer. The length of the exposed platinum wire between the U-tube and the electrometer was so short that it did not need a metal screen to guard it against irregular influences. An india-rubber tube (metal, metallically connected with the guard cylinder, would have been better) from an ordinary blowpipe bellows was connected to the uninsulated end of the U-tube. Air was blown through it steadily for nearly an hour. With the sulphuric pumice in the other branch the electrometer rose in the course of three-quarters of an hour to about nine volts positive. When the pumice was moistened with water, instead of sulphuric acid, no such effect was observed. The result of the first experiment proves decisively that the passage of the air through the U-tube gave positive electricity to the sulphuric acid, and therefore sent away the dried air with negative electricity. A corresponding experiment with fragments of chloride of calcium instead of sulphuric pumice gave a similar result. In repetition of the experiments, however, it has been noticed that the strong positive electrification of the U-tube seemed to commence somewhat suddenly when a gurgling sound, due to the bubbling of air through free liquid, whether sulphuric acid or chloride of calcium solution, in the bend of the U-tube, began to be heard. We intend to repeat the experiments with arrangements to prevent any bubbling of the air through liquid.

We have repeated our original experiment with pumice moistened with water in the insulated ∪-tube, and with an uninsulated ∪-tube filled with sulphuric pumice between the bellows and the insulated tube, so that the air entering it is artificially dried. With this arrangement the insulated ∪-tube was negatively electrified by the blowing of the air through it; but this electrification may have been due to the negative electrification of the dry entering air to be expected from the result of our first experiment. We intend to repeat the experiment with artificially dried *and dis-electrified* air blown through the ∪-tube containing pumice moistened with water.

2. *Preliminary Experiments for comparing the Discharge of a Leyden Jar through different Branches of a Divided Channel. By* Lord KELVIN, *P.R.S., and* ALEX. GALT, *B.Sc., F.R.S.E.*

In these experiments the metallic part of the discharge channel was divided between two lines of conducting metal, each consisting in part of a test-wire, the other parts of the two lines being wires of different shape, material, and neighbourhood, of which the qualities in respect to facility of discharge through them are to be compared.

The two test-wires were, as nearly as we have been hitherto able to get them, equal and similar, and similarly mounted. Each test-wire was 51 cm. of platinum wire of ·006 cm. diameter and 12 ohms resistance, stretched straight between two metal terminals at the ends of a glass tube. One end of the platinum wire was soldered to a stiff solid brass mounting; the other was fixed to a fine spring carrying a light arm for multiplying the motion. The testing effect was the heat developed in the test-wire by the discharge, as shown by its elongation, the amount of which was judged from a curve traced, by the end of the multiplying arm, on sooted paper carried by a moving cylinder. Two of Lord Kelvin's vertical electrostatic voltmeters, suitable respectively for voltages of about 10,000 and 1,500, were kept constantly with their cases connected with the outer coatings of the leyden, and their insulated plates with the inside coatings of the leyden.

I. In the experiments hitherto made the two wires to be tested have generally been of the same length. When they were of the same material, but of different diameters, the testing elongation showed, as was to be expected, that the test-wire in the branch containing the thicker wire was more heated than the test-wire in the other branch. In a continuation of the experiments we hope to compare hollow and tubular wires of the same external diameter, and same length and same material.

II. With wires of different non-magnetic material—for example, copper and platinoid—of the same length, but of very different diameters, so as to have the same resistances, the testing elongations were very nearly equal.

III. In one series of experiments the tested conductors were two bare copper wires, each ·16 cm. diameter, 9 metres long, and resistance ·085 ohm, which, it will be observed, is very small in comparison with the 12 ohms in each of the platinum test-wires. One of the copper wires was coiled in a uniform helix of forty turns on a glass tube of 7 cm. diameter. The length of the helix was 35 cm., and the distance from centre to centre of neighbouring turns therefore $\frac{7}{8}$ cm. The middle of the other copper wire was hung by silk thread from the ceiling, and the two halves passed down through the air to the points of junction in the circuit. The elongation of the test-wire in this channel was more than twice as much as that of the test-wire in the channel, of which the helix was part.

IV. One hundred and seventy-one varnished pieces of straight soft iron wire were placed within the glass tube, which was as many as it could take. This made the testing elongation ten times as great in the other channel.

V. The last comparison which we have made has been between iron wire and platinoid wire conductors. The length of each was 502·5 cm. The diameter of the iron wire was ·034 cm., and its resistance 6·83 ohms. The diameter of the platinoid wire was ·058 cm., and its resistance 6·82 ohms. Each of these wires was supported by a silk thread from the ceiling, attached to its middle (as in III. and IV.

for one of the tested conductors). Fourteen experiments were made, seven with the test-wires interchanged relatively to the branches in which they were placed for the first seven. The following table shows the means of the results thus obtained, with details regarding the electrostatic capacities of the leyden-jars and the voltages concerned in the results.

In each case four leyden-jars, connected to make virtually one of capacity ·02742 microfarad, were charged up to 9,000 volts, and discharged through divided channel. The energy, therefore, in the leyden before discharge was $11{\cdot}105 \times 10^6$ ergs. In each of the first three cases 1,450 volts were found remaining in the jars after discharge; in each of the last four 1,400.

Energy remaining in leyden after discharge	Energy used	Elongation of testing wires in cms.			
		In channel containing platinoid	means	In channel containing iron	means
$\cdot 29 \times 10^6$ ergs	$10{\cdot}82 \times 10^6$ ergs	·01794	·01829	·01226	·01239
”	”	·01861		·01247	
”	”	·01832		·01244	
$\cdot 27 \times 10^6$ ergs	$10{\cdot}84 \times 10^6$ ergs	·01823	·01836	·01276	·01261
”	”	·01828		·01280	
”	”	·01828		·01244	
”	”	·01865		·01244	

The mode of measuring the elongation of the test-wires was, as may be understood from the preceding description, somewhat crude, but it is reassuring to see that the mean results in the cases of 10·82 and 10·84 megalergs of energy used are so nearly equal. The ratios for the two circuits are, in the two cases, respectively 1·48 and 1·46. The conclusion that the heating effect in the test-wire in series with the platinoid wire is nearly one-and-a-half time as great as that of the test-wire in series with the iron is certainly interesting, not only in itself, but in relation to Professor Oliver Lodge's exceedingly interesting and instructive experiments on alternative paths for the discharge of leyden-jars, described in his book on 'Lightning Conductors and Lightning Guards,' which were not decisive in showing any general superiority of copper over iron of the same steady ohmic resistance, but even showed in some cases a seeming superiority of the iron for efficiency in the discharge of a leyden-jar. Our result is quite such as might have been expected from experiments made eight years ago by Lord Rayleigh and described in his paper 'On the Self-induction and Resistance of Compound Conductors.'[1]

3. *On Photo-electric Leakage. By* Professor OLIVER J. LODGE, *F.R.S.*

4. *Report on the Present State of our Knowledge of Thermodynamics, Part II., 'On the Laws of Distribution of Energy and their Limitations.' By* G. H. BRYAN, *M.A.*—See Reports, p. 64.

5. *On the Possible Laws of Partition of Rotatory Energy in Non-colliding Rigid Bodies. By* G. H. BRYAN, *M.A.*—See Reports, p. 98.

6. *On the Law of Molecular Distribution in the Atmosphere of a Rotating Planet. By* G. H. BRYAN, *M.A.*—See Reports, p. 100.

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[1] *Phil. Mag.*, vol. xxii. 1886, p. 469.

7. *On the Application of the Determinantal Relation to the Kinetic Theory of Polyatomic Gases. By* Professor LUDWIG BOLTZMANN.—See Reports, p. 102.

FRIDAY, AUGUST 10.

(Joint Meeting with Section G.)

The following Papers were read:—

1. *On Planimeters. By* Professor O. HENRICI, *F.R.S.*

This Paper was ordered by the General Committee to be printed *in extenso*.
See Reports, p. 496.

2. *Note on the Behaviour of a Rotating Cylinder in a Steady Current. By* ARNULPH MALLOCK.

3. *On the Resistance experienced by Solids moving through Fluids. By* Lord KELVIN, *P.R.S.*

4. *A Discussion on Flight was opened by* Mr. HIRAM S. MAXIM.

SATURDAY, AUGUST 11.

The Section was divided into three Departments.

The following Papers and Reports were read:—

DEPARTMENT I.

A Method of Determining all the Rational *and* Integral *Algebraic Integrals of the Abelian System of Differential Equations. By* W. R. WESTROPP ROBERTS, *M.A.*

The method of treatment adopted in this paper, though pregnant with facts calculated to throw light on the general theory of Abelian functions and integrals, has been strictly confined to the determination of the forms of the algebraic integrals which are rational and integral functions of the variables and arbitrary constants which enter into them. Jacobi's method of treatment enables us to determine many of the algebraic forms of the integrals of the differential system, but none of them are rational or integral, and even in the case of elliptic integrals the one rational algebraic integral which the differential equation possesses, involving an arbitrary constant, is arrived at with some difficulty from the known forms of the integral which are not integral functions of the variables. In the case of hyper-elliptic integrals I am not aware that rational and integral forms have yet been given. The result of the present paper enables us to write down for any case the forms of the algebraic integrals which are all rational and integral.

Again, being given *one* of these forms, *all* the remaining ones can be determined by the application of an operator δ.

With regard to the method adopted in the paper, I first show how to find all the conditions which must be satisfied in order that a binary quantic of this degree $2n$ may be a perfect square, and show that they may be all found from a matrix which I call the *square matrix* for the functions of the degree $2n$. I have not entered on any discussion of these curious conditions and their intimate relationship, which are well worthy of examination, insomuch as their number is the number of ways in which $4n-3$ quantities may be taken $2n-2$ together, and are still equivalent to but n conditions.

The Abelian system of differential equations may be written

$$\sum \frac{z^i dz}{\sqrt{A_0 f(z)}} = 0,$$

where there are m quantities z_1, z_2, z_m, and $m-1$ equations, as is clear from the above method of writing them if we suppose that i can have any integer value from $i=0$ to $i=m-2$; also $f(z)=z^{2m}+P_1 z^{2m-1}+P_2 z^{2m-2}+ \ldots P_{2m}$.

I now form a function which I call $F(z)$, and which is of the degree $2m-2$ in the following manner.

Let

$$\begin{aligned} \phi(z) &\equiv (z-z_1)(z-z_2) \ldots (z-z_m) \\ &= z^m + p_1 z^{m-1} + \ldots p_m; \\ L(z) &\equiv z^m + P_1 z^{m-1} + \lambda_2 z^{m-2} + \lambda_3 z^{m-3} + \ldots \lambda_m; \end{aligned}$$

$L(z)$ introducing $m-1$ quantities $\lambda_2, \lambda_3 \ldots \lambda_m$;

then I write

$$F(z) \equiv A_0 \left\{ f(z) + \{\phi(z)\}^2 - 2\phi(z) L(z) \right\},$$

which is easily seen to be of the degree $2m-2$ in z; also its *source* is

$$A_0 \left\{ p_m^2 - 2\lambda_m p_m + P_{2m} \right\}.$$

Now I say this function $F(z)$ must be a perfect square. Forming, then, the various conditions from the *square matrix* of $F(z)$, we have *all* the forms of the algebraic integrals of the Abelian system

$$\sum \frac{z^i dz}{\sqrt{A_0 f(z)}} = 0,$$

which are rational and integral, involving $m-1$ arbitrary constants $\lambda_2, \lambda_3 \ldots \lambda_m$.

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2. *On a Graphical Transformer.*[1] *By* A. P. TROTTER.

This instrument is intended for the expeditious replotting of a curve with transformed ordinates without calculation or scaling. It consists of a rectangular frame and a curved template or cam, and is used in conjunction with a straight ruler.

Let the scale of one system of ordinates be set off upwards along the edge of one of the perpendiculars, and the scale of the other along the edge of the other perpendicular, but downwards. Join the corresponding points on the scale by straight lines. The envelope of this system of lines may be thus drawn, and to the curve a cam is cut in thin wood or ebonite.

To transform any ordinate, set the frame against a T square, adjusting the edge to the ordinate, and the zero to the zero of the scale. Set a needle at the extremity of the ordinate; bring a straight edge to touch the needle and the cam; prick off a point at the intersection of the straight edge with the other edge of the frame. This point determines the length of the new ordinate.

An instrument provided with a logarithmic cam was exhibited. With this instrument the product or quotient of two curves can be found by adding or subtracting the logarithms of the ordinates; or the logarithms of a series of observations can be plotted. Cams for other functions can be easily made; but it must be remembered that the action of the instrument is, as it were, arithmetical rather than geometrical, for a cam is useful only with reference to its own scale.

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[1] Printed *in extenso* in the *Electrician*, August 17, 1894, vol. xxxiii. p. 465.

This instrument not only enables transformations of a definite and known character to be made, but is equally applicable for transforming in an empirical manner. The curve drawn by a recording voltmeter or ammeter may thus be replotted for estimation of area, or other graphical analysis, without any knowledge of the law of the particular instrument. In other words, a correction can be applied to a curve.

The cams are easy to make, and even if carelessly cut cannot possibly give rise to cumulative errors. It is convenient to use the upper edge of the ruler instead of the edge which rolls on the cam. The curve must in this case be set out with the ruler, and used with the same ruler, or one of the same width. The rolling of a straight edge on a cam has been used in a photometer, invented by Mr. W. H. Preece and the author,[1] for the automatic calculation of the squares of the displacements of a lamp.

3. *On a Linkage for the Automatic Description of Regular Polygons.*
By Professor J. D. Everett, *F.R.S.*

Let any number of equal bars be jointed together in the manner of a lazytongs, so as to lie in two superposed planes, each bar in one plane (except the end bars) being jointed at both ends, B, D, and at one intermediate point, C, to the corresponding points of three bars in the other plane; but instead of the two distances BC, CD being equal, as in the ordinary lazytongs, let them be unequal, CD being the greater. All the bars are to be precisely alike. They will form a frame with one degree of freedom, resembling in this respect an ordinary lazytongs; but instead of the three series of points, B_1 B_2 . . . , C_1 C_2 . . ., D_1 D_2 . . ., being ranged in three parallel straight lines, they will be ranged in three concentric circular arcs, two of which, namely, B_1 B_2 . . . and D_1 D_2 . . . , formed by the inner and outer ends respectively, will subtend the same angle at the common centre O. In place of the rhombuses of the ordinary lazytongs we shall have kites, and the axes of all the kites will pass through O.

When the frame, supposed to be at first pushed close in, is gradually opened out so as to increase the widths and diminish the lengths of the kites, the curvatures will increase in a double sense: the arcs formed by the inner and outer ends will increase in length, and at the same time their radii will diminish. The common angle which they subtend at the centre will accordingly increase very rapidly, and may easily amount to 360° or more. When it is exactly 360°, the first and last points B will coincide, as will also the first and last points D. In this position the points D will be the corners of one regular polygon, the points C of another, and the points B of a third. We have thus an automatic arrangement for constructing a regular polygon with any number of sides. Also, as the axes of successive kites are equally inclined to one another, we have the means of dividing an arbitrary angle into any number of equal angles—an end which can also be attained by employing the principle that equal arcs in a circle subtend equal angles at a point on the circumference, or, still more conveniently, by making use of the fact that those bars which correspond to parallel bars in an ordinary lazytongs are equally inclined each to the next.

Strictly speaking, the figures obtained are not polygons, but stars, which can be converted into regular polygons by joining the ends of their rays. It frequently happens that the curvature can be extended far beyond 360°, giving a succession of regular stars with a continually decreasing number of rays.

Let each of the bars above described be lengthened at its inner end, B, till a point A is reached, such that the three distances, AB, AC, AD, are in geometrical progression. Then it can be shown that the radius OA of the circular arc formed by the ends A is constant, and equal to AC. Hence the common centre, O, can be found automatically by employing two additional bars of length AC, jointed together at one end, O, and jointed at their other ends to two of the points A. These bars OA may be called *radius bars*, the other bars, AD, being called *long bars*. The proof is easily gathered from an inspection of the accompanying figure, in which OA_1, OA_2, OA_3, OA_4 are radius bars, A_1D, A_4D long bars, and A_2C_3, A_3C_2 portions of two other long bars whose remaining portions are indicated by dotted lines. The figure contains two equal and similar jointed rhombuses, OC_2, OC_3, and three similar kites, OB, DB, DO. Each of the bars A_2C_3, A_3C_2 is cut in a fixed ratio at the point of crossing, B, the ratio of the smaller part to the whole being $OA_1 : A_1D$; hence we can have joints both at B and D, as well as at O, and the other corners of the rhombuses, without hampering the motion.

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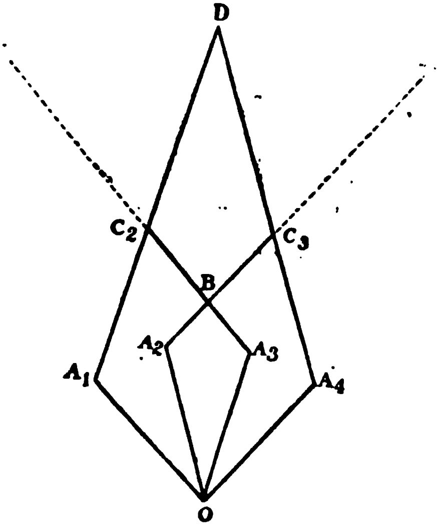
[1] *Proc. Inst. C.E.*, vol. cx. p. 81.

Two radius bars are in general sufficient to give the centre, but we may in theory attach a radius bar at each point A, and joint their other ends together at one point, O, which will be the common centre. There are difficulties in the way of realising this design in practice, except with a very limited range of movement; but by carefully selecting the best order of superposition of the bars, and by thinning off the radius bars towards the end where they are all superposed, it has been successfully carried out in two of the frames exhibited, each consisting of ten long bars and ten radius bars. The other frame exhibited illustrates the first paragraph of this abstract, and consists of ten bars BD. The number of bars in this frame might be increased indefinitely.



If m denote the ratio of a long bar to a radius bar, or of the longer to the shorter sides of a kite, 2α the angle between the two shorter sides, and 2β the angle between the two longer sides of a kite, then, by considering one of the two triangles into which a kite is divided by its axis, we have $\sin\alpha/\sin\beta = m$, which is equivalent to

$$\tan\tfrac{1}{2}(\alpha-\beta)/\tan\tfrac{1}{2}(\alpha+\beta)=(m-1)/(m+1).$$

$\alpha+\beta$ is one of the angles of a rhombus, and $\alpha-\beta$ is the angle between two consecutive rays of a star.

In the case of the frame first described, consisting of $2n$ bars BD, when a regular star of n rays is formed, the central figure in the frame will be a polygon of $2n$ sides, whose angles are alternately $\alpha+\beta$ and $360°-2\alpha$.

For the radii of the circular arcs we have (calling a radius bar unity)

$$OA = 1,\ OC = 2 \cos \tfrac{1}{2} (\alpha + \beta),$$

$$OD = \sqrt{\left\{ m^2 + 1 + 2m \cos (\alpha + \beta) \right\}},$$

$$OB = \sqrt{\left\{ 1 + \frac{1}{m^2} + \frac{2}{m} \cos (\alpha + \beta) \right\}}.$$

OA is a side of a rhombus, and OC one of its diagonals. OD is the length of the largest kites, and OB the length of the inner kites.

Any two of these four radii may be equal, except that OD is always greater than either OC or OB.

When OA = OB we have $2 \cos (\alpha+\beta) = -1/m = -\sin \beta \sin \alpha$; whence $2\alpha + \beta = 180°$, $\cos \alpha = \sin \frac{1}{2} \beta = 1/(2m)$.

$$\begin{aligned} OA = OC &\text{ gives } \alpha + \beta = 120°. \\ OA = OD &\quad ,, \quad \cos (\alpha + \beta) = -m/2. \\ OB = OC &\quad ,, \quad \cos (\alpha + \beta) = -(m+1)/(2m). \end{aligned}$$

Of the two twenty-bar frames exhibited, one has joints at both B and D, with $m = 2$; the other has no joints at B, and its ends can be made to overlap so much as to give a three-rayed star.

4. *On the Addition Theorem.* *By* Professor MITTAG-LEFFLER.

Professor Mittag-Leffler called attention to the intimate relation which exists between the modern theories of ordinary non-linear differential equations and the addition theorem. He explained how the theories created by Fuchs, Poincaré, and Picard may be generalised by making use of the considerations introduced by Weierstrass, and showed the direction which this generalisation must take. He also pointed out that the addition theorem itself may be generalised to a very considerable extent, and that the resulting theory has important applications to the theory of differential equations.

5. *Note on a General Theorem in Dynamics.* *By* Sir ROBERT BALL, *F.R.S.*

The following general theorem establishes a relation which characterises the particular type of screw-chain homography which is of importance in dynamics.

Let α, β, γ, &c., be a series of screw-chains about which a mechanical system of any kind with any degree of freedom can twist.

Let η be the impulsive screw-chain which, if the system were at rest, would make the system commence to move by twisting about α.

Let ξ be the corresponding screw-chain related to β, and ζ to γ, &c.

Then the two systems of screw-chains, α, β, γ, &c., and η, ξ, ζ, &c., are homographic.

But this homography is not of the most general type. It was only lately that I succeeded in ascertaining the further general condition that the screw-chains must satisfy.

Let $\varpi_{\alpha\xi}$ denote the virtual coefficient of the screw-chains α and ξ; *i.e.*, let this symbol denote the rate at which work is done by the unit of twist velocity about α against the unit wrench on ξ.

Then every three screws α, β, γ in one group are connected with their three correspondents η, ξ, ζ in the other group by the relation

$$\varpi_{\alpha\xi}\, \varpi_{\beta\zeta}\, \varpi_{\gamma\eta} - \varpi_{\alpha\zeta}\, \varpi^{\beta\eta}\, \varpi_{\gamma\xi} = 0.$$

6. *The Asymmetric Probability Curve.* *By* F. Y. EDGEWORTH, *M.A.*

The asymmetric probability curve is the general form of the law of error. It may be obtained by solving a system of partial differential equations, which is the generalisation of the system given by Mr. Morgan Crofton for the symmetrical probability curve ('Encyclopædia Britannica,' article on Probabilities, p. 781, equations 45, 46). The generalised system may be written:

$$\left\{\begin{array}{ll} (1) & y + x\dfrac{dy}{dx} + 2k\dfrac{dy}{dk} + 3j\dfrac{dy}{dj} = 0 \\ (2) & \dfrac{dy}{dk} = \dfrac{1}{2}\dfrac{d_2 y}{dx^2} \\ (3) & \dfrac{dy}{dj} = -\dfrac{1}{6}\dfrac{d_3 y}{dx^3} \end{array}\right.$$

where y is the frequency with which any error x occurs; x is measured from the centre of gravity of errors; k is the sum of squares of errors measured from that point; j the similarly measured sum of cubes. The solution of the system is a series of ascending powers of x, each term of which consists of a series of ascending powers of $j \div k^{\frac{3}{2}}$. If j is put $=0$, the curve being treated as symmetrical, the series reduces, as it should, to the ordinary probability curve

$$y = \frac{1}{\sqrt{\pi}\sqrt{2k}}\, e^{-\frac{x^2}{2k}}$$

If $j \div k^{\frac{3}{2}}$ is small, the curve being only slightly asymmetrical, the series reduces to a curve which is indicated by Todhunter as being related to the ordinary probability curve as a second is to a first approximation (Todhunter, 'History of Probabilities;' Laplace, art. 1002, p. 568). This slightly asymmetrical probability curve may be used to correct the theory of *correlation* investigated by Messrs. F. Galton and H. Dickson ('Proc. Roy. Soc.,' 1886), and by the present writer ('Phil. Mag.,' November and December 1892). Whereas, according to the first approximation, the most probable y corresponding (or 'relative') to any assigned (or 'subject') value of x lies on a right line passing through the origin, according to the second approximation the locus of correlates is a parabola.

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7. *On the Order of the Groups related to the Anallagmatic Displacements of the Regular Bodies in* n-*Dimensional Space.* *By* Prof. P. H. SCHOUTE.

1. The groups related to the regular bodies in ordinary space have been amply studied by F. Klein in his 'Vorlesungen über das Ikosaeder' (Leipzig, Teubner, 1884). There in every case the order of the group has been found by enumeration of the possible positions; so the remarkable fact that this order is always twice the number of edges is not observed.

I now wish to publish a simple general principle by means of which the order of the group may be easily determined. This principle will prove to be capable of immediate extension to n-dimensional space.

2. *General Principle.*—The manner of coincidence of the regular body ABCD . . . with the given position PQRS . . . (say the *orientation* of ABCD . . . with respect to PQRS) is determined if the position of the vertex A and that of the edge AB have been assigned.

Therefore the order of the group is the product of the number of vertices by the number of edges passing through a given vertex.

This product is evidently the twofold of the number of edges.

Four-dimensional Space (S^4).

3. *General Principle extended.*—The orientation of the cell ABCD . . . with reference to the given position PQRS . . . is determined, if the position of the vertex A, that of the edge AB through A, and that of the face ABC through AB

have been assigned. So the order of the group is the product of three numbers, viz., the number of vertices, the number of edges containing a given vertex, and the number of faces passing through a given edge.

4. For the six regular cells of S^4 the results are:

Five-cell . . .	(C_5) . . .	$5 \times 4 \times 3 = 60$
Eight-cell . . .	(C_8) . . .	$16 \times 4 \times 3 = 192$
Sixteen-cell . . .	(C_{16}) . . .	$8 \times 6 \times 4 = 192$
Twenty-four-cell . .	(C_{24}) . . .	$24 \times 8 \times 3 = 576$
Hundred and twenty-cell	(C_{120}) . . .	$600 \times 4 \times 3 = 7{,}200$
Six hundred-cell . .	(C_{600}) . . .	$120 \times 12 \times 5 = 7{,}200$

5. *Remarks.*—(*a*) A deeper study proves the group of the five-cell to be holohedrically isomorph with that of the icosahedron.

(*b*) In the pairs of cases (C_8, C_{16}) and (C_{120}, C_{600}) the results are equal. This is due to the fact that these pairs of regular cells are reciprocal polars of each other with respect to a hypersphere.

(*c*) The order of the group is equal to $2r$ times the number of faces, r representing the number of vertices situated in any face.

Five-dimensional Space (S^5).

6. *General Principle extended.*—The order of the group is the product of four numbers, viz., the number of vertices, the number of edges through a given vertex, the number of faces through a given edge, and the number of limiting bodies adjacent at a given face.

7. Results:

Six-being . . .	(B_6) . . .	$6 \times 5 \times 4 \times 3 = 360$
Ten-being . . .	(B_{10}) . . .	$32 \times 5 \times 4 \times 3 = 1{,}920$
Thirty-two-being . .	(B_{32}) . . .	$10 \times 8 \times 6 \times 4 = 1{,}920$

8. *Remarks.*—(*a*) The cases (B_{10}) and (B_{32}) are reciprocal polars of each other, &c.

(*b*) The order of the group is equal to $6r$ times the number of limiting bodies, r representing the number of vertices situated in any limiting body.

Space of n-*Dimensions* (S^n).

9. The extension of the principle is evident. The results are:

$n+1$-being (B_{n+1}) . .	$(n+1)\,n\,(n-1)$ . . .	$\times 4 \times 3 = \frac{1}{2}(n+1)!$
$2n$-being (B_{2n}) . . .	$2^n \,.\, n\,(n-1)$	$\times 4 \times 3 = 2^{n-1} \,.\, n!$
2^n-being (B_{2^n}) . . .	$2n \,.\, 2\,(n-1)$	$\times 6 \times 4 = 2^{n-1} \,.\, n!$

10. *Remarks.*—(*a*) The cases (B_{2n}) and (B_{2^n}) are reciprocal polars of each other, &c.

(*b*) The order of the group is equal to $(n-2)!\,r$ times the number of limiting beings of $n-2$ dimensions, r representing the number of vertices situated in each of these.

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8. *On Mersenne's Numbers. By* Lieut.-Colonel **Allan Cunningham**, *R.E.*, *Fellow of King's College, London.*

These are numbers of form $N = 2^p - 1$, where p is prime. Lucas has shown that N is composite, and contains the factor $(2p+1)$ when p and $(2p+1)$ are *both* prime, and p is of form $(4i+3)$.

Such numbers N may for shortness be called *Lucasians.* The highest Lucasians, determinable by the existing tables of primes (extending to 9,000,000), are given by

$$p = 4{,}499{,}591 \text{ and } 4{,}499{,}783,$$

and these are the only values of p yielding Lucasians in the range of 500 numbers between 4,499,500 and 4,500,000. An interesting group is given by

$$p = 2^3 + 3 = 11 ;\ p = 2^7 + 3 = 131 ;\ p = 2^{15} + 3 = 32{,}771 ;$$

and these are the *only* numbers of form $(2^x + 3)$ yielding Lucasians when x not > 26. Higher values go beyond the tables of primes.

Complete list of primes p of form $(4i + 3)$, with $(2p + 1)$ also prime, when p not $> 2{,}500$; these all give composites for N, and $(2p + 1)$ is a factor of N.

$p =$ 11, 23, 83, 131, 179, 191, 239, 251, 359, 419, 431, 443, 491, 659, 683, 719, 743, 911, 1,019, 1,031, 1,103, 1,223, 1,439, 1,451, 1,499, 1,511, 1,559, 1,583, 1,811, 1,931, 2,003, 2,039, 2,063, 2,339, 2,351, 2,399, 2,459.

It seems *probable* that primes of one of forms $p = (2^x \pm 1)$, $(2^x \pm 3)$ will, with exception of those yielding Lucasians, *generally yield prime values* of N, and that *no others will*; all the known (and conjectured) prime Mersenne's numbers fall under this rule.

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9. *End Games at Chess.* *By* Lieut.-Colonel ALLAN CUNNINGHAM, *R.E.*, *Fellow of King's College, London.*

Investigation of the number of positions in all the 'end games' at chess when there are only two or three pieces on the board. The results are:—

P = Total number of positions
C = Number of checkmate positions
S = Number of stalemate positions
I = Number of indifferent positions
} with a given set of pieces.

Number of Pieces	Names of Pieces		Number of Positions			
	Black	White	C	S	I	P
2	K	K	0	0	3,612	3,612
3	K	K and Q	324	144	223,476	223,944
3	K	K and R	216	68	223,660	223,944
3	K	K and Kt	0	40	223.904	223,944
3	K	K and B (unnamed) .	0	136	223,808	223,944
3	K	K and WB or BB . .	0	68	111,904	111,972
3	K	K and P (unnamed) .	0	18	195,966	195,984
3	K	K and QRP or KRP .	0	2	24,466	24,468
3	K	K and QKtP or KKtP .	0	3	24,505	24,508
3	K	K and QBP or KBP .	0	3	24,505	24,508
3	K	K and QP or KP . .	0	1	24,507	24,508

DEPARTMENT II.

10. *Experiments showing the Boiling of Water in an open Tube.* *By* Professor OSBORNE REYNOLDS, *F.R.S.*

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11. *Report of the Committee on Earth Tremors.*—See Reports, p. 145.

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12. *Report of the Committee on Meteorological Photography.*—See Reports, p. 143.

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13. *Report of the Committee on Solar Radiation.*—See Reports, p. 106.

14. *Report of the Committee on Underground Temperature.* See Reports, p. 107.

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15. *Report of the Ben Nevis Committee.*—See Reports, p. 108.

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16. *On Recent Researches in the Infra-Red Spectrum.*

By Dr. S. P. Langley.

This paper was ordered by the General Committee to be printed *in extenso.*—See Reports, p. 465.

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17. *A new Determination of the Ratio of the Specific Heats of certain Gases.*

By O. Lummer *and* E. Pringsheim.[1]

When a perfect gas expands adiabatically from the pressure p_1 to the pressure p_2, while its absolute temperature decreases from T_1 to T_2, we have

$$T = \frac{\log\left(\frac{p_1}{p_2}\right)}{\log\left(\frac{p_1}{p_2}\right) - \log\left(\frac{T_1}{T_2}\right)}$$

where T means the ratio of the two specific heats. Therefore T can be determined by four corresponding values of p_1, p_2, T_1, and T_2. For this purpose we experimented in the following way.

A copper balloon, nearly globular, containing about 90 litres was placed in a bath of water whose temperature was maintained constant within 0°·01 C. and could be measured by a thermometer. Let this temperature be T_1. The balloon was filled with a gas, well dried and pure, which was compressed to the pressure p_1, measured by a manometer of sulphuric acid communicating with the balloon. Then the gas was allowed to escape into the atmosphere through an aperture of the balloon. So it expanded to the atmospheric pressure p_2 given by the barometer. In this way the quantities p_1, p_2, and T_1 can be found easily. The only difficulty is to determine the temperature T_2 of the gas at the moment when the expansion is finished and the pressure has attained the value p_2. For this purpose we need a thermometer showing the variable temperature of the gas instantaneously, that is, a thermometer of a negligible small mass.

A thermometer of the required qualities was formed by a strip of platinum of an extremely small thickness, which is soldered at both ends to two copper wires insulated from each other and introduced air-tight into the balloon. From these the strip hangs down freely in the middle of the balloon. The strip of platinum with its conducting wires formed one arm of a Wheatstone bridge, so that we were able to measure its electrical resistance, and hence its temperature at every moment. The strip was prepared by the method first used for wires by Wollaston, and adopted for strips by Lummer and Kurlbaum. It was cut out of a platinum silver plate composed of a platinum plate with the thickness 0·6μ and a silver plate 6μ thick. The middle part of the strip had a length of 10 cm. and a breadth of about 0·2 mm., while the two ends were formed by conducting laps 1·5 cm. long and about 4 mm. broad. The silver was removed by nitric acid only in the middle narrow part, so that the resistance of the conducting laps perfectly disappeared in comparison with that of the middle part. But also these conducting laps are thin enough to take at a short distance from the ends the temperature of the surrounding gas, as is easily proved by calculation. In this way the fall of temperature at the ends of the strip is perfectly eliminated. The resistance of the strip amounted to 87 ohms at the temperature of 17° C.; the variations measured by us were between 1 and 4 ohms.

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[1] The original source of publication is the Smithsonian Institution in Washington, which kindly granted liberal assistance from the Hodgkins Fund for carrying on this investigation.

In order to find the lowest temperature T_2 reached by the gas while expanding we have only to measure the smallest value which the resistance of the strip takes during the expansion. We worked in the following way. First, when the balloon is filled with compressed gas of the temperature T_1, the Wheatstone bridge is equilibrated so that no current is going through the galvanometer. This state we call the first equilibrium. Then the galvanometer arm is opened and out of the arm of the bridge opposite to the strip a part of the resistance is taken away, so that the resistance of this arm now is lower than that of the strip. Now the gas is allowed to escape out of the balloon, the temperature of the gas is lowered, and the resistance of the strip decreases and approaches that of the opposite arm. Immediately after the end of the expansion, at the moment when the strip has the smallest resistance, we close the galvanometer circuit, and now the galvanometer shows by its deflection if the resistance of the strip at this moment is higher or lower than the resistance of the other arm. Only in the case when both resistances are exactly equal does the galvanometer remain at rest. This state we call the second equilibrium. This second equilibrium is always to be attained by a systematic variation of the initial pressure of the gas, and when it occurs the galvanometer remains at rest for some seconds, showing that during this time there is no appreciable conduction of heat to the gas surrounding the platinum strip.

In this way four corresponding values of p_1, p_2, T_1, and T_2 are found.

A small error in these experiments is caused by the heat radiating from the walls of the balloon to the strip cooled by the expanding gas, but it is possible to determine the amount of this error by experiment. For this purpose we executed the experiments described above, once with a simple platinum strip, the second time with the same strip after having blackened it by platinum black. In the second case the error due to radiation is increased in the same proportion, as the absorbing power of blackened platinum is larger than that of the uncovered, and therefore we found a smaller value of T than before. The relation of the two absorbing powers was determined by special experiments, and so we found the correction necessary to remove the error resulting from radiation.

The gases on which we worked were atmospheric air, oxygen, carbonic acid, and hydrogen.

The results obtained with the naked strip were:

Air	O	CO_2	H
1·3994	1·3941	1·2940	1·4063

The probable error of the result:

± 0·00024	± 0·00024	± 0·00031	± 0·00020

To these values we must add the correction caused by radiation:

+ 0·0021

Consequently we get the values of

T.

Air	O	CO_2	H
1·4015	1·3962	1·2961	1·4084

That we found a much greater value for hydrogen than all former experimenters is the best proof of the superiority of our method. All other methods failed with hydrogen because the heat conduction of this gas is very great, and consequently the experiments were not adiabatic. Our method gives also for hydrogen the second equilibrium of the Wheatstone bridge lasting for more than a whole second, showing that also here the expansion is quite adiabatic.

DEPARTMENT III.

18. *A Method for accurately Determining the Freezing-point of Aqueous Solutions which freeze at Temperatures just below* 0° *C. By the Late* P. B. LEWIS. *Communicated by* DR. MEJER WILDERMANN.

The thermometers used for measuring minute variations in temperature were graduated, the one to read to thousandths the other to hundredths of a degree. The total volume of the solution used in the various determinations was 1,250 c.c. The beaker containing the liquid for examination was placed on a felt cushion, wrapped in thin gutta-percha, inside a zinc vessel which acted as an air-chamber. The cover of this vessel was provided with a circular opening into which fitted a cork, holding the thermometers. The stirring of the liquid was effected by a porcelain stirrer which consisted of two parallel porcelain plates, in which there were corresponding holes for the thermometers to pass through, and besides these eight round holes so arranged that the holes in the upper plate did not correspond with those in the lower plate. On moving the stirrer up and down currents are sent in all directions. The thermometers are kept uniformly at a temperature of 0° C., even when not in use, by keeping them plunged in a glass beaker, filled with ice and water at 0° C. This second beaker is contained in a similar zinc vessel, which acts as a cold-air chamber. The two zinc vessels, the one containing the distilled water and the other the solution to be examined, are placed in a larger zinc vessel, which acts as an ice-bath, and which is encased in a yet larger zinc vessel, so that there should be a cushion of air of some centimetres' thickness between the two. The outermost zinc vessel stands on a thick felt mat, and is wrapped in a thick felt cover. The ice-bath was covered over as far as possible with pieces of asbestos cloth. By these means a fairly constant temperature is maintained in the bath. The temperature of the ice-bath should only vary between 1°·8 and −2° when the temperature of the room is 12° to 18°, and only between −2°·1 and 2°·2 at a temperature of 25°. It is necessary for a successful experiment to overcool the solution by about 0°·7 to 1°. Under these conditions the most accurate determination of the freezing-point can be obtained: the mercury in the large thermometer has sufficient time to become exactly of the temperature of the solution, the ice is obtained in the form of thin films, and the freezing-point remains fairly constant for from ten to fifteen minutes, though slight variations of from 0°·0001 to 0°·0002 occur, and in the more concentrated solutions of 0°·0003. As regards the action of the thermometers it is important to know how far the capacity of their bulbs is affected by the pressure caused by a rise, especially a rapid rise, of mercury in the stem, and how quickly the bulb recovers from the expansion or contraction which variations of pressure or temperature cause. It can only be here stated that if such variations exist they lie within the limits of ordinary experimental error, namely, 0°·0001, 0°·0002, and rarely 0°·0003. On the other hand, it was found that when the more delicate thermometer had been allowed to remain for several hours at the ordinary temperature, a rise in its indication of the freezing-point could be observed for many days afterwards, and a long-continued exposure to a rise or fall of atmospheric pressure causes a variation of about 0°·0003 in the reading of the freezing-point for 1 mm. rise of the barometer. A similar variation is produced in the reading of the smaller thermometer. In the case of very dilute solutions only those determinations of the freezing-point which have been made during almost constant conditions of atmospheric pressure are to be depended on. While the column of mercury is rising the stirring must be maintained together with a light tapping with the fingers on the cork. The maximum is reached when further tapping causes no rise of the mercurial column. When this point has been reached readings are made every minute for from eight to ten minutes. The readings are made with a small lens. After the constant point has been observed for from eight to ten minutes the form taken by the ice produced is examined. If the experiment has been successful the ice will have formed in fine films and in considerable quantity throughout the solution. An account of this investigation will be given in the Journal of the Chemical Society, and in the 'Zeitsch. f. physik. Chemie.'

19. *The Influence of Temperature upon the Specific Heat of Aniline.*[1]

By E. H. GRIFFITHS, *M.A.*

The author drew attention to the fact that water is by no means an ideal liquid for calorimetric purposes, its great capacity for heat rendering it unsuitable for operations such as that known as 'the method of mixtures.' Again, we have but little knowledge concerning the changes caused in its specific heat by changes in temperature, and its vapour pressure at low temperatures is sufficient to cause a constant leakage of heat by the processes of evaporation.

In all these respects aniline appears to be superior.

The method adopted for determining the specific heat of aniline was an electrical one, and the specific heat was ascertained over a range of from 15° to 52° C. The heat developed by rapid stirring was balanced by heat lost by convection, conduction, &c., and the rate of rise at different temperatures, due to the electrical supply only, was ascertained.

The results are closely represented by the formula

$$s = 0{\cdot}5156 + (t-20) \times {\cdot}0004 + (t-20)^2 \times {\cdot}000002.$$

The values obtained by means of this equation do not in any case differ from the experimental results by more than 1 in 2,000.

20. *On some Photometric Measures of the Corona of April* 1893.

By Professor H. H. TURNER, *M.A.*

The present paper is merely a preliminary note on some measures of the photometric intensity of the corona on photographs taken at Fundium by the British expedition in April 1893.

The measures (of density of deposit at various points on the plates) were made at South Kensington by the kindness of Captain Abney, who lent me his apparatus for the purpose. This apparatus has been described by him elsewhere in detail; and here it is only necessary to remark that a beam of light is divided by a plane glass plate, part being transmitted and part reflected. The photograph is placed in one beam, and a 'rotating sector' in the other. The beams are then caused to illuminate two small screens placed side by side, and the aperture of the rotating sector is varied until the illuminations are equal. The aperture of the sector is then read, and the reading is a direct indication of the density of the photograph at the particular point under examination. In this note it is desired to call attention to one or two points which the observations, though as yet incomplete, have suggested.

(1) I cannot help referring to the beauty and simplicity of the rotating sector. The ease and accuracy of the observations are such as I was quite unprepared for; and it seems to me that the apparatus is indispensable to the astronomical photographer. I look forward to making use of it in a large variety of ways.

(2) The points examined up to the present have been distributed along four radii respectively north, south, east, and west from the moon's centre. If the density be tabulated according to distance from the moon's limb, the resulting curves are very similar to 'error' curves, with the maximum at the moon's limb, and deviations from a smooth curve are very small.

(3) The results for the four radii are very similar; and the mean of the east and west radii gives a curve almost identical with that for the mean of the north and south radii (the means being taken to eliminate the distance between the centres of sun and moon). The general form of the corona at 'maximum' is in accordance with this result, but I was not prepared for so close an accordance as the figures show.

(4) The density of the film has by no means reached uniformity at the edge of the plate, even in the small scale photographs, which allow of measures up to 70′ or 80′ from the limb. It is possible that the light causing this deposit is not

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[1] See *Phil. Mag.*, 1894.

true corona, but at the same time it seems probable that there may be a closer correspondence between photographs, and the eye observations which claim a large 'extension' of the corona, than has hitherto been supposed.

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21. *On Photographs of Spiral and Elliptic Nebulæ.*
By Isaac Roberts, *D.Sc., F.R.S.*

Seven photographs of spiral nebulæ and four of elliptic nebulæ were exhibited as lantern slides on a screen, and their forms and structures shown and described.

The photographs were taken with a reflecting telescope of twenty inches aperture and long exposures of the sensitised plates, and much additional knowledge concerning the objects was revealed by the photographs.

The author claimed that the photographs proved the following statements:—

1st. That the existence of spiral nebulæ is a physical reality.

2nd. That the convolutions of the spirals proceed from, or else converge to, a stellar or star-like centre, and are arranged symmetrically with reference to each other and to the stellar centre.

3rd. That the convolutions, or spirals, are without exception broken up into stars and star-like condensations, which are involved in nebulous matter, denser in the lines of the convolutions and fainter between them.

The cause of the vortical motions of the nebulæ was suggested to be collisions between bodies in space, or else shrinkage of the diffused mass, producing concentrated gravitational effects.

The elliptic nebulæ were shown to be constituted with a stellar centre surrounded by dense nebulosity, outside which are alternate rings of nebulosity with spaces between them having little if any nebulosity in them, each nebula, as a whole, presenting the appearance of a stellar system now in course of evolution from a nebula of gigantic dimensions.

By taking periodically a series of photographs and comparing them with each other the changes that may take place in the nebulæ will, sooner or later, be made manifest.

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22. *On the Formation of Soap Bubbles by the Contact of Alkaline Oleates with Water.* *By* Professor G. Quincke, *F.R.S.*

This paper was ordered by the General Committee to be printed *in extenso.*—See Reports, p. 475.

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23. *On the Effect of Gases on the Surface Tension and Electrical Conductivity of Soap-films.* *By* H. Stansfield.

A preliminary note was read on some experiments undertaken at the request of Professor Rücker for the purpose of investigating whether the remarkably high conductivity of thin soap-films found by Professors Reinold and Rücker was produced by the surrounding gas.

Experiments were also made to test whether the gas in which a film is formed affected the fall in surface tension which takes place. In both cases it was found that the gas was not the efficient cause of the phenomenon observed.

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24. *On the Velocity of the Hydrogen Ion through Solutions of Acetates.*
By W. C. Dampier Whetham, *M.A.*

The velocity of the hydrogen ion in dilute aqueous solutions of ordinary mineral acids was calculated by Professor F. Kohlrausch from the conductivities, and came out ·0030 centimetre per second when the potential gradient was one volt per centimetre. Dr. Oliver Lodge measured its velocity through chlorides, and found ·0029.[1]

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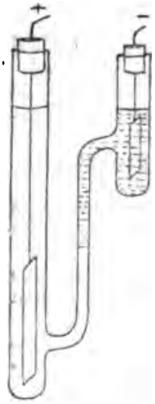
[1] See *B.A. Report*, 1886, p. 389.

The molecular conductivity of solutions of acetic acid is abnormally low, and in order to test whether the velocities of the ions were reduced in the same proportion an experiment was made by a modification of Lodge's method, which I had already used for tracing the course of other ions.[1] A solution of sodium acetate made first alkaline with soda and coloured red with phenol-phthallein was divided into two parts, and one of them decolourised with a little acetic acid. The solutions were then placed in a kind of U tube with a vertical connecting limb (see figure), so that the motion of the junction between the coloured and uncoloured solutions could be easily followed. A current was passed upwards across the boundary and the hydrogen ion travelled with it, forming acetic acid and decolourising the phenolphthallein. It was found better in this case to use agar-jelly solutions, which had been abandoned for other ions as introducing unnecessary complications. The velocity of the hydrogen ion through a jelly solution of sodium acetate of strength 0·07 gramme equivalent per litre, when driven by a potential gradient of one volt per centimetre, came out ·000065 cm. per second. Through a solution of hydrochloric acid of 0·1 gramme equivalent strength its velocity is ·0030. The ratio of these numbers is 1:46. The specific molecular conductivity of an acetic acid solution of strength 0·07 is to that of a solution of hydrochloric acid of strength 0·1 as 1 : 59. I have not yet been able to devise a method for measuring the velocity of the acetic acid group $(C_2H_3O_2)$ in an acid solution, but the numbers given above show that at all events the velocity of the hydrogen ion is reduced in about the same proportion as the conductivity.



MONDAY, AUGUST 13.

The following Papers were read:—

1. *On the Results of a New Analytical Representation of the Distribution of Magnetic Force on the Surface of the Earth. By* AD. SCHMIDT, *of Gotha.*

The author has obtained in the first place three series in terms of spherical harmonics for the three quantities $\alpha X \sin v$, $\beta Y \sin v$, γZ, where X, Y, Z are the three components of the earth's magnetic force, v is the colatitude, and α, β, γ are three factors, nearly equal to unity, depending on the spheroidal shape of the earth. By a method which he has previously explained in the 'Archiv des deutschen Seewarte,' 1893, he deduces from these series three others which give the magnetic potential on the surface of the earth: (1) as far as depends on forces inside the earth, (2) on forces outside the earth. The third series represents that part of the magnetic forces which cannot be expressed in terms of a potential, but must be due to electric currents traversing the earth's surface. The first series has been calculated to fifty-two, the second and third to forty-three coefficients. The result shows an appreciable fraction of the magnetic force to be due to outside effects, and also gives currents traversing the earth's surface, amounting on an average to about 0·1 ampere per square kilometre.

The author points out that thoroughly reliable results can only be obtained after our knowledge of magnetic forces has been extended to higher latitudes in the southern hemisphere.

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[1] *Trans. R.S.*, 1893, A, p. 337.

2. *A Suggested Explanation of the Secular Variation of Terrestrial Magnetism.* *By* ARTHUR SCHUSTER, *F.R.S.*

It is a matter of great importance to ascertain whether we must consider interplanetary space to be a conductor of electricity or not. If there is an appreciable conductivity the magnetic system of the earth will, owing to its rotation, induce currents which will react on the earth in a twofold manner. There will be, in the first place, a mechanical effect tending to increase the length of the day, and, secondly, a magnetic effect tending to displace the magnetic axis. It is the object of this communication to give the results of some numerical calculations referring to the magnitude and nature of these reactions.

The problem is of interest apart from any applications to terrestrial magnetism. Given a magnetic sphere rotating in a conducting medium, what are the mechanical and magnetic forces acting on the sphere in consequence of electric currents induced in the medium?

The mathematical solution is easily obtained from Lamb's equations for currents induced in spherical conductors; and, without entering into any details of calculation, I here state the principal results for the case when the sphere is uniformly magnetised about an axis not coinciding with the axis of rotation.

If the medium is either perfectly conducting or perfectly non-conducting, there will be no mechanical effect tending to stop the rotation of the sphere; but for all finite conductivities there will be a couple opposing the rotation which is a maximum for a certain specific resistance of the medium.

If the radius of the sphere is R, the angular velocity ω, the specific resistance ρ producing the maximum retardation is given by the relation

$$\rho = 1{\cdot}4\,\mathrm{R}^2\omega,$$

where the numerical factor is approximate only.

For the earth: $\mathrm{R} = 6{\cdot}4 \times 10^8$; $\omega = 7{\cdot}27 \times 10^{-5}$

$$\rho = 4{\cdot}17 \times 10^{13}.$$

The resistance indicated by this number is such that if 4·17 volts were applied to the two sides of a plate having a thickness of one centimetre there would be a current of 10^{-4} amperes per square centimetre. I do not know of any facts which would make such a conductivity an impossible one, consistently with the extreme tenuity of matter which we know must exist in space. The next point to consider is the actual value of the maximum retarding couple. In C.G.S. units, and for a sphere having the same size and magnetic moment of the earth, it is $1{\cdot}9 \times 10^{24}$. If this couple was to act continuously it would diminish the earth's rotational velocity to the extent of one second per day in 14,000 years. Early records of solar eclipses show that the earth as a timekeeper has lost time, but authorities do not agree as to how much. Two causes tending to alter the length of the day have hitherto been considered, tidal friction tending to retard it and the contraction of the earth tending to increase it. To this we must now add a possible retardation due to the conductivity of the medium.

The maximum magnetic couple calculated above is about six times that given by George Darwin for the effect of tidal friction, and it would by itself have produced a very marked effect in historical times, and according to Lord Kelvin the effects of the earth's contraction are very small. It is, of course, very improbable that the conductivity of space is just that required for the maximum effect. If the conductivity is 100 times less, the couple produced would be equal to the tenth part of the maximum couple, and such a couple would be impossible to separate at present from the other effects, tending to alter the length of the day. There is, therefore, a very large range of electric conductivity, within which that of space may lie without an appreciable effect on the length of the day being produced in historical times.

Turning our attention next to the magnetic reactions, we find that these will displace the magnetic axis towards the geographical pole and round it from east to west. If the earth behaved like a steel sphere, not subjected to any shocks or changes of temperature, a certain displacement would take place once for all, but no rotation such as is required to produce the secular variation. The constantly renewed displacement of the magnetic axis, if it is due to the suggested cause, must be produced by a continuous change inside the earth. A possible explanation suggests itself in the secular cooling of the earth, owing to which more and more of its iron becomes susceptible to magnetisation. This virgin iron will be free to adjust its magnetic axis to the magnetic forces acting on it, and a continuous displacement of the axis must result. It must be acknowledged, however, that, even taking account of this possibility, it is difficult to see how a rotation of the axis can be kept up for several revolutions. Some light might be thrown on the question by an experimental investigation to discover a possible effect of great pressure on the temperature at which iron loses its magnetic properties. Whether there are any appreciable magnetic effects due to electric currents outside the earth may, of course, be established by an analysis of the magnetic forces on the surface of the earth. I understand that A. Schmidt and Neumayer have already made much progress with such an analysis, and I am preparing an independent calculation with special reference to the outside forces.

The results of this investigation may be stated thus:—

(1) The mechanical reactions on the earth of currents induced in space, assumed to be a conductor of electricity by the rotation of its magnetic system, are insufficient to produce an appreciable lengthening of the day in historical times, unless the conductivity lies within certain narrow limits. The absence of any marked effect cannot therefore be brought forward as an argument against the conductivity of space.

(2) The magnetic reactions of the same current, taken in conjunction with the secular cooling of masses of iron inside the earth, tend to produce a displacement which in kind is the same as that actually observed in the secular variation. But whether quantitatively the variation can be explained in this way is very doubtful.

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3. *On the Construction of a Delicate Galvanometer.*

By ARTHUR SCHUSTER, *F.R.S.*

Maxwell has shown how a galvanometer must be wound in order to produce the maximum magnetic field for a given resistance. The present communication is intended to show what the advantage gained would be if the winding which is theoretically best could be adopted. Assuming the cavity in which the magnet is suspended to be cylindrical, the sensitiveness of the galvanometer will vary with the square root of the resistance, and inversely as the square root of the radius of the cavity. The smallest angle which can be read without making the system astatic will also depend on the diameter of the mirror; a point which has been neglected in the construction of some recent galvanometers. Taking the resistance of the galvanometer to be one ohm, the diameter of the cylindrical cavity to be one centimetre, and the width of the reflecting mirror to be also one centimetre, the smallest current which a galvanometer will show with a horizontal force of 0·17 is under different conditions as follows:—

	Amperes
If wound in the theoretically best possible way . . .	$1{\cdot}60 \times 10^{-8}$
If wound on a bobbin of rectangular section of the best dimensions, the wire being uniform in each layer, but changing from layer to layer so as to give the best results .	$2{\cdot}00 \times 10^{-8}$
If wound on a bobbin of rectangular section with uniform wire, the dimensions of the bobbin being the most favourable	$2{\cdot}14 \times 10^{-8}$

The advantage gained by having the winding in the way which is theoretically the best is therefore not very marked.

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4. *On the Minimum Current audible in the Telephone.*[1]

By Lord RAYLEIGH, *Sec. R.S.*

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[1] Published in the *Phil. Mag.*, xxxviii. pp. 285–295, September 1894.

5. *An Attempt at a Quantitative Theory of the Telephone.*[1]
By Lord RAYLEIGH, *Sec. R.S.*

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6. *On the Amplitude of Sonorous Waves which are but just Audible.*[2]
By Lord RAYLEIGH, *Sec. R.S.*

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7. *On the Production of Beat-tones from Two Vibrating Bodies whose Frequencies are so High as to be separately Inaudible. By* ALFRED M. MAYER.

In the first attempts to obtain such tones use was made of steel rods of rectangular section, the lengths of whose sides are to one another as 4 : 5. These rods were chamfered on one edge in the length of the rods, so that by striking a rod on this edge both component tones of the rod were obtained simultaneously with the resultant tone, the latter being the lower second octave of the graver tone of the rod. It was impossible to obtain beat-tones by this method by reason of the short duration of the resultant when the frequencies of the two component vibrations of the rod surpass the limit of audibility.

Several bird-call whistles were made in order to obtain the proper proportions to give frequencies surpassing the limit of audibility and yet to give no hissing sounds.

The most effective whistle has a diameter of air-disc of 5 mm., and the holes in the opposed plates of the disc are 1·2 mm. in diameter. The distance of the discs of the whistles is varied and adjusted by a micrometer-screw.

With these whistles beat-tones have been obtained when the vibrations from either whistle alone were inaudible.

Beat-tones have also been obtained by Dr. Koenig and myself in Paris with tuning-forks whose frequencies surpass the limit of audibility.

Dr. Koenig anticipated me in the production of these beat-tones by several months, and has actually used those beat-tones in tuning-forks whose frequencies surpass the limit of hearing.

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8. *On the Variation of the Modulus of Elasticity with Change of Temperature as determined by the Transverse Vibration of Bars at Various Temperatures. By* ALFRED M. MAYER.

Lord Rayleigh in his 'Theory of Sound' discusses the transverse vibration of a bar free at both ends and supported under its two nodes, showing that we can compute the frequency of the bar if we know the velocity of sound in the length of the bar and the dimensions of the bar. The expression of these relations reduces to $N\ 1{\cdot}0279\ V\ \frac{t}{l^2}$, in which t and l are the thickness and length of the bar.

To see how closely the formula gave the transverse frequency of bars, I had rods of 1·5 m. in length, 2 cm. in width, and $\frac{1}{2}$ cm. in thickness, and of uniform section, made of cast steel, aluminium, brass, glass, and white pine. These rods were vibrated longitudinally at 20° C. and their frequencies determined by Koenig's tonometer, whence we obtained V. Out of each rod were cut three bars, each about 20 cm. long, and these bars, also at 20° C., were vibrated transversely. The mean departure of the computed from the observed numbers of transverse vibrations was $\frac{1}{325}$, the computed frequency being always in excess of the observed except in the case of glass, where the computed was below the observed frequency.

The close concordance between theory and observation shows that by vibrating a bar at various temperatures the variation of the modulus of elasticity with temperature can be obtained. We observe N at various known temperatures of the bar, whence V is computed, and the modulus is $M = \frac{V^2 d}{g}$. As l, t, and d have different values at different temperatures, the coefficient of expansion of each bar experimented on was determined, also the density of each bar at 40° C., and the dimensions and density computed for each temperature of the vibrating bar.

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[1] Published in the *Phil. Mag.*, xxxviii. pp. 295-301, September 1894.

[2] *Ibid.*, xxxviii. pp. 365–370, October 1894.

Though the moduli thus obtained are not so accurate as those given by other more precise methods, yet I think that the *variation* of the modulus with temperature is thus obtained.

Tables and curves of results of the experiments on bars of glass, cast steel, Bessemer steel, brass, bell-metal, two specimens of aluminium, silver, and zinc were exhibited before the Section.

The moduli of these substances are lowered by increase of temperature as follows. Heating from 0° to 100° lowers the modulus of

Glass	1·13	per cent.	of its modulus	at 0°
Cast steel . . .	2·21	„	„	„
Bessemer steel . .	3·08	„	„	„
Brass	3·67	„	„	„
Bell-metal . . .	4·27	„	„	„
Aluminium (American)	5·37	„	„	„
„ (French) .	5·66	„	„	„

Silver heated from 0° to 60° has its modulus lowered 2·47 per cent. of its modulus at 0°. Zinc heated from 0° to 62° has its modulus lowered 6·04 per cent. of its modulus at 0°.

9. *On an Apparatus for Measuring small Strains.*
By Professor J. A. Ewing, *F.R.S.*

10. *On Mirrors of Magnetism.*
By Professor Silvanus P. Thompson, *D.Sc.*, *F.R.S.*

The author has found by experiment that a sheet of iron, if sufficiently large and thick, acts magnetically as a mirror, giving virtual images of a magnet pole placed in front.

The image of a pole placed at any distance in front (provided the mirror is large as compared with the distance) is situated at an equal distance behind the mirror, exactly as in optical reflexion by a plane mirror.

The image of a north pole is a south pole, just as the image of a right hand is a left hand.

If the magnet pole is moved away from the sheet of iron, the image moves away at an equal speed in the reverse direction.

If the sheet of iron be moved up toward the magnet pole, the image moves up at double the velocity, as optical images do.

If a magnet pole is placed between two parallel large sheets of iron, the effect is the same as if there were a double series of images in an indefinitely extended row, the images being, however, of alternate polarity.

The action of a spherical surface of iron as a spherical mirror presents some curious points. Only virtual images are produced whether the mirror be convex or concave. There is no spherical aberration, and the images, though of reversed polarity and perverted, are not inverted. These last points are deduced from the experiments, and have not yet been independently verified.

The method of experiment has been to produce magnetic poles or fields by means of coils supplied with electric currents. These poles or fields were investigated by means of an exploring coil or coils connected with a galvanometer, the throw of which was observed when the primary current was turned on or off. The throw obtained when the mirror was absent was compared (c) with that obtained when the mirror was present, (*b*) with that obtained when, the mirror being absent, the geometrical position of the coil was occupied by an actual coil of the same magnetic moment as the 'image.'

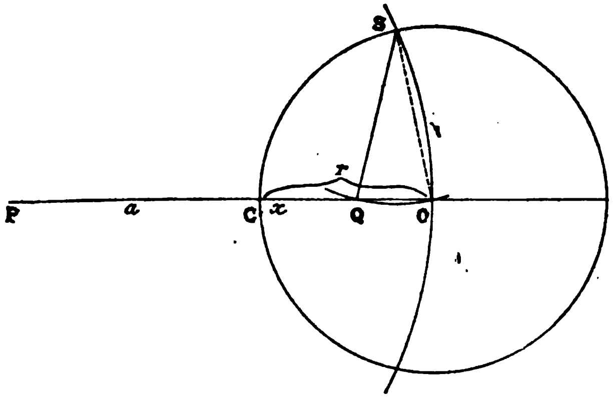
Iron in thin sheet as used for tin-plate is not thick enough to form a perfect mirror. A piece of boiler-plate, ½ inch thick and rather less than 3 feet square, formed a perfect plane mirror for poles placed not more than 4 or 5 inches away from its centre. A long solenoid 200 centimetres long, 1·5 centimetre diameter, uniformly wound with twelve turns per centimetre with a wire capable of carrying 15 amperes without overheating, was used in one series of experiments to produce a pole.

In the case of a convex spherical surface of iron of infinite magnetic permeability, and of radius of curvature r, the object being a pole of strength m situated at a point at a distance a from the middle of the mirror surface, the image is a pole of strength $-m\frac{r}{a+r}$. Its distance x behind the surface is equal to $r-\frac{r^2}{a+r}$, or $\frac{ar}{a+r}$.

$$\begin{array}{lll} \text{If} & a=0 & x=0 \\ & a=r & x=\tfrac{1}{2}r \\ & a=\infty & x=r \end{array}$$

The image of an infinitely distant pole is at the centre, not as in the case of the optical image half-way between surface and centre.

The following simple construction gives the position of the image of any point-pole outside.



Let P be the position of the point-object, and O the centre of the spherical surface. Join PO, and with P as centre describe the arc OS. Then with centre S and OS as radius describe arc OQ cutting PO in Q. Q is the image of P.

For a concave mirror the construction is reversed by finding successively the centres of the arcs. The image is a pole having strength $=-m\frac{a+r}{r}$, where a is the distance of the image from the surface $=\frac{rx}{r-x}$.

Both formulæ show that as r increases to infinity $a=x$.

The whole of the experimental work has been carried out for me by Mr. Miles Walker.

11. *The Volume Changes which accompany Magnetisation in Nickel Tubes.*

By Professor C. G. KNOTT, *D.Sc.*

The method of experiment was similar to that employed in the determination of corresponding changes in iron and steel tubes, and already described in a former communication.[1] Three nickel tubes, cut originally from the same solid bar, were turned and bored. They were of the same length (47 cm.) and the same external diameters (4·2 cm.). The internal diameters were as follows:—No. I., 2·543 cm.; No. II., 1·586 cm.; and No. III., 0·692 cm.

The decrease of volume in the tube of widest bore (No. I.), when subjected to a longitudinal field of 600, was so large that it had to be measured with the naked eye. The liquid meniscus in the capillary tube moved outwards through a distance of 3 cm., which corresponded to a volume change of 2·4 cubic millimetres. This, with a total internal volume of 224·47 cubic centimetres, gives a dilatation of fully -10^{-5}.

In the following table some of the more striking results are indicated. Under each heading of field is a column containing the corresponding cubical dilatations for the three tubes.

Cubical Dilatations × 10^7.

Field =	10	15	25	35	62	102	200	400	600
Tube I. .	−0·5	0	+0·8	0	−9	−24	−67	− 98	−110
Tube II. .	—	−0·7	0	+1	0	−10	−53	− 79	− 87
Tube III. .	—	—	+1·0	+2·5	+9	0	−84	−207	−236

Thus in lowest fields the cubical dilatation is negative in Tubes I. and II. Very soon, however, it becomes positive, but changes back to negative in still higher fields, and so continues to the highest fields used. In Tube III. there is no evidence of the negative dilatation in low fields, so that with it there is only one change of sign. The thicker the wall, the higher the field in which the change of sign takes place. In moderate and high fields the changes of volume are distinctly greater in nickel than in iron or steel.

12. *On Hysteresis in Iron and Steel in a Rotating Magnetic Field.*

By FRANCIS G. BAILY, *M.A.*

It has long been surmised that the hysteresis in iron may have different values according to the mode of variation of the direction of magnetisation. As a deduction from Professor Ewing's molecular theory of magnetism Mr. James Swinburne pointed out that the value of the hysteresis in an alternating field should be different, and obey a different law, from that of iron in a rotating magnetic field, the latter probably being the smaller, especially at a high induction. The point has not, however, received any experimental verification until now.

The experiments here described consisted in causing a powerful electromagnet to revolve on an axis concentric with the bore of the pole pieces, which formed parts of a cylinder. The magnetic field between the two pole pieces rotated with the electromagnet producing it. In the polar cavity was placed a finely laminated cylindrical armature of iron or steel carried by hollow centres in fixed supports, and held by a spring attached to the armature spindle and to the fixed support respectively. On rotating the field-magnet there is a force due to the hysteresis of the armature tending to cause it to revolve with the magnet. This is prevented by the spring, and the deflexion of the spring is a measure of the torque exerted on the armature, which is proportional to the hysteresis in the armature per reversal, and is independent of the speed of revolution of the magnet. The deflexion is observed by the movement of a beam of light reflected from a small mirror on the armature, and on to a circular scale. Varying currents were sent round the field-magnet coils, producing different values of induction in the armature.

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[1] See *B.A. Reports*, 1892, p. 659.

At a low induction the hysteresis is small and increases but slowly, the range corresponding with the first part of the B/H curve, and the shape of the curve being similar to that given by an alternating field. With increasing induction the value of the hysteresis rises more rapidly, but does not continue to increase at a uniform rate. When B = 12,000 the rate of increase of the hysteresis diminishes, though the curve still rises rapidly. When B = 17,000 the curve begins to bend over, reaching a maximum at 18,000 or 18,500, and rapidly falls when the induction is further increased, until when B = 21,000 the hysteresis is about one-third of its maximum value. Higher inductions could not be satisfactorily reached with the apparatus, but there was no indication of any diminution in the rate of decrease of the hysteresis.

Both soft charcoal iron and hard high carbon steel were tested, and found to give the same results, the value in the steel reaching a maximum at an induction of 16,000.

These experiments show that there is no simple relation between hysteresis and induction. The three stages of magnetic displacement each have a sharply defined position on the hysteresis curve, the critical value occurring just on the knee of the induction curve. The agreement of the results with the theoretical deduction constitutes a strong verification of the molecular theory of magnetism.

The above results hold good for all speeds up to seventy revolutions per second, which was the highest speed obtained.

13. *On the Vibrations of a Loaded Spiral Spring.*
By L. R. Wilberforce, *M.A.*

The author pointed out that by comparing the two periods of vibration of a body attached to a spiral spring of small angle the ratio of the torsional and flexural rigidities of the wire or strip forming the spring could be found, and hence, if the wire were homogeneous, isotropic, and of circular section, Poisson's ratio for its material could be determined.

Some experiments were shown illustrating the normal modes of vibration of such a system, and the transference of energy from up-and-down to twisting vibrations, and back again, which can be effected when the periods are nearly equal.

TUESDAY, AUGUST 14.

The Section was divided into three Departments.

The following Papers and Report were read:—

Department I.

1. *On Fuchsian Functions. By* Professor Mittag-Leffler.

Professor Mittag-Leffler, after referring to a recent investigation by one of his pupils, M. G. Cassel, spoke of the advantages and inconveniences connected with the expression of automorphic functions by means of the Fuchsian or Kleinian θ series. He showed how the theory of the θ functions may be brought into connection with that of the Abelian functions, and that an expression given by M. Schottky for a certain class of automorphic functions is, in fact, applicable to all these functions. He then referred to his own researches on the invariants of linear differential equations, and pointed out that Günther, in his paper in 'Crelle's Journal,' has not fully realised the true nature of these researches.

2. *On Ronayne's Cubes.* *By* Professor H. HENNESSY, *F.R.S.*

Some years since a box containing a pair of equal cubes was placed in the author's hands, and he found that one of these could have its parts displaced so as to leave a peculiarly shaped shell, through which the second cube passed without any difficulty. Groups of twin crystals of a cubical form have been long known, but their grouping could rarely admit of such a structure as the cubes referred to present.

It is manifest that a cube passed through another in the direction of the diagonal of the square would leave two triangular prisms, but in order to connect these prisms two flanges with interior sloping faces should be attached. The thickness of these flanges in two directions, as well as the angle of inclination of the sloping faces, are all connected by geometrical conditions which permit of the solution of the problem of the construction of the shell of the first cube. The author was unable to find the solution of the problem originally published by the inventor of the cubes, Mr. J. Ronayne, some time about the middle of the last century. Under these circumstances he completed the inquiry, and on comparing the results with the measured dimensions of the prisms and flanges which constitute the shell of the first cube he found the perfect concordance between the calculated and measured dimensions. When x represents the distance from a corner of the cube to the edge of the flange, and a the side of the cube, then θ, the inclination of the sloping face to the face of the cube, is found to be represented by

$$\sin\theta = \frac{2a(a\sqrt{2}-2x)}{3a^2+4x^2-4ax\sqrt{2}}$$

The edge of each cube is 1·92 inch, and θ is found both by measurement and by the above formula to be 9° 45′ nearly.

3. *On a Property of the Catenary.* *By* Professor H. HENNESSY, *F.R.S.*

In the course of inquiry into some hydraulic questions the author found that the catenary of maximum area under a given perimeter may be inscribed in a semicircle.[1] Hence, if the radius of the semicircle is one foot, the chain hung within it when in a vertical plane will be one yard. Thus the two fundamental standards of English measure are connected with the catenary of maximum area.

4. *A Complete Solution of the Problem, 'To find a Conic with respect to which two given Conics shall be Reciprocal Polars.'* *By* J. W. RUSSELL, *M.A.*

In the author's 'Elementary Treatise on Pure Geometry,' p. 147, a construction is given in the case in which the given conics intersect in distinct points. This construction was extended to the cases of the conics touching or having three-point contact. The method in the case of double contact was different. Taking U to be the common pole and AB the common chord, through U draw any line meeting the conics in PP′, QQ′ respectively. Let X Y be the double points of the volution PQ, P′Q′ or of PQ′, P′Q. Then the conic required is the conic touching UA at A and UB at B, and passing through X or Y. This method holds, when suitably modified, in the case of four-point contact.

5. *The Impossibility of Trigraphic Fields of Spaces.*
By J. W. RUSSELL, *M.A.*

The simplest trigraphic form is that generated by three points P, P′, P″ on three lines AB, A′B′, A″B″, these points being connected by a relation of the form

$$a_1k'\,k'\,k' + a_2k'\,k'' + \;.\;.\;.\; + a_3k + \;.\;.\;.\; + a_8 = 0$$

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[1] *Proc. Roy. Soc.*, vol. xliv. p. 106.

where $a_1, a_2 \ldots$ are constants, and $k = AP/PB$, $k' = A'P'/P'B$, $k'' = A''P''/P''B''$. Starting from this form, various trigraphic forms of increasing complexity can be built up, as in the geometry of homographic figures. But it is impossible to finally construct trigraphic figures on the analogy of homographic figures. To prove this, take A B C D, A′ B′ C′ D′, A″ B″ C″ D″ as corresponding tetrahedrons in the assumed trigraphic figures, and suppose that the variable points P, P′, P″ of the figures subtend trigraphic pencils at the axes (BC, CA, AB), (B′C′, C′A′, A′B′), (B″C″, C″A″, A″B″) respectively. Then, if P and P′ move on straight lines, it is shown that P″ moves on a surface, and not on a straight line, as it should do.

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6. *On Maxwell's Method of deriving the Equations of Hydrodynamics from the Kinetic Theory of Gases. By* Professor LUDWIG BOLTZMANN.

It is well known that the equations of hydrodynamics for a viscous fluid, as Maxwell was the first to show, can be derived from the hypothesis of the kinetic theory of gases. But Maxwell's method is not quite satisfactory. Many terms of the equations must be neglected in order to obtain the hydrodynamical equations in their usual form. Even if this course in most cases is justifiable, it cannot be rigorously proved that such is the case, and the mathematician is not satisfied. The following question arises, Is this a defect of the theory of gases, or is it rather one of hydrodynamics? Are these terms required by the theory of gases not an essential correction of the equations of hydrodynamics? Will it not be possible to find cases where these two theories are not in accord, and to decide by experiments between them? Maxwell himself raised this question, and he found that the ordinary assumption, that in gases which conduct heat the pressure is everywhere equal in all directions, is only approximately true. A short time before his death he published an ingenious method of treating these questions, viz., the application of spherical harmonics to the theory of gases. Maxwell only gave in a few words the results of his calculations, in three short notes, which are included in square brackets in his paper, 'On Stresses produced by Conduction of Heat in Rarefied Gases.' These three notes show evidently that he must have made a long and elaborate investigation on this subject a short time before his death, which, however, has not been published. I have treated the same subject by a different method, and have also found that many corrections of the equations of hydrodynamics can be derived from the theory of gases. It will be not easy, but perhaps not impossible, to test some of these differences by experiment. I have not yet published these results, because they do not agree in all respects with the results briefly announced by Maxwell, and the danger of falling into errors in this subject is great.

With regard to this I beg the British Association to make efforts to ascertain if the manuscript of the investigation made by Maxwell on the application of spherical harmonics to the theory of gases is still in existence, and, if this manuscript should be lost, to encourage physicists to repeat these calculations.

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7. *On the Invariant Ground-forms of the Binary Quantic of Unlimited Order. By* Major P. A. MACMAHON, *R.A., F.R.S.*

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8. *Principes fondamentaux de la Géométrie non-euclidienne de Riemann.* Par P. MANSION, *professeur à l'Université de Gand.*

I. M. Gérard a exposé, sous une forme simple et rigoureuse, les principes fondamentaux de la géométrie non-euclidienne de Lobatchefsky, dans un article inséré dans la livraison de février 1893 des 'Nouvelles Annales de Mathématiques' (3ᵉ série, t. xii, pp. 74–84).

On peut démontrer d'une manière analogue les principes fondamentaux de la géométrie non-euclidienne de Riemann, en partant des deux propriétés fondamen-

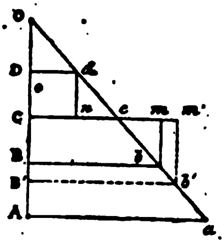
tales suivantes : 1° Deux droites riemanniennes situées dans un même plan se coupent en deux points situés à une distance 2Δ toujours la même quelles que soient les deux droites (voir De Tilly, 'Essai sur les principes fondamentaux de la Géométrie et de la Mécanique,' dans les 'Mémoires de la Société des Sciences Physiques et Naturelles de Bordeaux,' 2ᵉ série, t. iii. 1ᵉʳ cahier, ch. i.). 2° La somme des trois angles d'un triangle est supérieure à deux droits (voir 'Mathesis,' août 1894, 2ᵉ série, t. iv., pp. 181–182).

II. On démontre, comme dans le cas de la géométrie lobatchefskienne, les théorèmes suivants :

1° Dans un triangle rectangle ayant pour hypoténuse z, pour côtés x, y, si z tend vers zéro, l'angle (z, x) restant constant $(x : z)$ tend vers une limite finie en décroissant ; $(y : z)$ tend aussi vers une limite finie, mais en croissant.

2° Si u et u', v et v' sont les côtés opposés d'un quadrilatère, trirectangle en (u, v), (u, v') et (v, u'), et si u tend vers 0, $(u' : u)$ tend en décroissant vers une limite $\phi(v)$, dépendant de v seulement ; on a d'ailleurs $(u' : u) < \phi(v')$.

III. THÉORÈME FONDAMENTAL.—On a $\phi(x+y) + \phi(x-y) = 2\phi(x)\phi(y)$. 1° Considérons le triangle OAa birectangle en A et a ; posons AB $= x - y$, AC $= x$, AD $= x + y$, OA $= \Delta$. Menons Bb, Cc, Dd perpendiculaires à OA et rencontrant Oa en b, c, d ; de b et d abaissons bm, dn perpendiculaires sur Cc. Soit encore BB$' = a$, B$'b'$ perpendiculaire à OA et rencontrant Oa en b', $b'm'$ une perpendiculaire à Cc.



2° D'après II. 1°, on a $cd > cb$; par suite, $cn > cm$, ou $2\,\mathrm{C}c > \mathrm{C}m + \mathrm{C}n$. Ensuite,

$$\frac{2\mathrm{C}c}{\mathrm{A}a} > \left(\frac{\mathrm{B}b}{\mathrm{A}a} : \frac{\mathrm{B}b}{\mathrm{C}m}\right) + \left(\frac{\mathrm{D}d}{\mathrm{A}a} : \frac{\mathrm{D}d}{\mathrm{C}n}\right),$$

et, à la limite (II. 2°),

$$2\phi(x) \geqq \frac{\phi(x-y)}{\phi(y)} + \frac{\phi(x+y)}{\phi(y)}.$$

3° D'après II. 1°, on a encore

$$\frac{cm}{cb} < \frac{cn}{cd} < \frac{\mathrm{C}c}{\mathrm{O}c},$$

ou

$$\frac{\mathrm{C}m - \mathrm{C}c}{cb} < \frac{\mathrm{C}c}{\mathrm{O}c}, \quad \left(\frac{\mathrm{B}b}{\mathrm{A}a} : \frac{\mathrm{B}b}{\mathrm{C}m}\right) - \frac{\mathrm{C}c}{\mathrm{A}a} < \frac{cb}{\mathrm{O}c}\,\frac{\mathrm{C}c}{\mathrm{A}a},$$

$$\frac{\mathrm{C}c - \mathrm{C}n}{cd} < \frac{\mathrm{C}c}{\mathrm{O}c}, \quad \frac{\mathrm{C}c}{\mathrm{A}a} - \left(\frac{\mathrm{D}d}{\mathrm{A}a} : \mathrm{C}n\right) < \frac{cd}{\mathrm{O}c}\,\frac{\mathrm{C}c}{\mathrm{A}a}.$$

Passant à la limite, il vient

$$\frac{\phi(x-y)}{\phi y} - \phi x \leqq \frac{y}{\Delta - x}\,\phi x\,;$$

$$\phi x - \frac{\phi(x+y)}{\phi y} \leqq \frac{y}{\Delta - x}\,\phi x\,;$$

et, par addition,

$$\phi(x-y) - \phi(x+y) \leqq \frac{2y}{\Delta - x}\,\phi x \phi y < \frac{2y}{\mathrm{D} - x}.$$

La fonction ϕ est donc continue.

4° On a

$$cb' > \mathrm{CB}' - \mathrm{B}'b' - \mathrm{C}c > \mathrm{CB} + a - 2\mathrm{A}a = \mathrm{CD} + a - 2\mathrm{A}a > cd + a - 2\mathrm{A}a.$$

On peut supposer $2\mathrm{A}a$ inférieur à la quantité fixe a; dans cette hypothèse, on a $cb' > cd$, $cm' > cn$, $\mathrm{C}m' + \mathrm{C}n > 2\mathrm{C}c$, puis

$$\left(\frac{\mathrm{B}'b'}{\mathrm{A}a} : \frac{\mathrm{B}'b'}{\mathrm{C}m'}\right) + \left(\frac{\mathrm{D}d}{\mathrm{A}a} : \frac{\mathrm{D}d}{\mathrm{C}n}\right) > \frac{2\mathrm{C}c}{\mathrm{A}a},$$

et, à la limite,

$$\frac{\phi\,(x-y-a)}{\phi\,(y+a)} + \frac{\phi\,(x+y)}{\phi\,(y)} \geqq 2\phi\,(x) \qquad (6)$$

5° Faisons tendre a vers zéro, il viendra

$$\frac{\phi\,(x-y)}{\phi\,(y)} + \frac{\phi\,(x+y)}{\phi\,(y)} \overset{=}{>} 2\phi(x).$$

6° Des relations (a), (b) on conclut le théorème.

IV. On démontre, comme dans le cas de la géométrie lobatchefskienne, les propositions suivantes:

1° On a $\phi\,(x) = \cos\left(\frac{x}{k}\right)$, k étant une constante.

2° Dans un triangle rectangle ayant pour hypoténuse z, pour côtés x, y on a

$$\cos\left(\frac{x}{k}\right)\cos\left(\frac{y}{k}\right) = \cos\left(\frac{z}{k}\right).$$

3° Dans un triangle ABC quelconque,

$$\cos\left(\frac{c}{k}\right) = \cos\left(\frac{a}{k}\right)\cos\left(\frac{b}{k}\right) + \sin\left(\frac{a}{k}\right)\sin\left(\frac{b}{k}\right)\cos \mathrm{C},$$

cos C étant une fonction qui ne dépend pas de la grandeur des côtés $a = \mathrm{BC}$, $b = \mathrm{AC}$, mais seulement de l'angle C opposé au côté $c = \mathrm{AB}$.

9. *Formulæ for Linear Substitution.*

By Professor E. B. Elliott, *M.A.*, *F.R.S.*

If $(\mathrm{A}_0, \mathrm{A}_1, \mathrm{A}_2, \ldots \mathrm{A}_n)\,(x, y)^n$

$$\equiv (a_0, a_1, a_2, \ldots a_n)\,(lx + my,\, l'x + m'y)^n$$

and Ω, O denote the operators

$$a_0\frac{d}{da_1} + 2a_1\frac{d}{da_2} + \ldots + na_{n-1}\frac{d}{da_n}$$

$$na_1\frac{d}{da_0} + (n-1)\,a_2\frac{d}{da_1} + \ldots + a_n\frac{d}{da_{n-1}}$$

respectively, then, P (a) denoting a rational integral homogeneous isobaric function of $a_0, a_1, a_2, \ldots a_n$, whose order and weight are i and w,

$$\mathrm{P}\,(\mathrm{A}) \equiv (lm' - l'm)^{in-w}\, m'^{\,2w-in}\, e^{\frac{m}{m'}\Omega}\; e^{\frac{l'm'}{lm'-l'm}\mathrm{O}}\, \mathrm{P}\,(a)$$

$$\equiv (lm' - l'm)^{w}\, l^{in-2w}\, e^{\frac{l'}{l}\mathrm{O}}\, e^{\frac{lm}{lm'-l'm}\Omega}\, \mathrm{P}\,(a)$$

DEPARTMENTS II., III.

A joint meeting with Section I. was held to discuss the two following Papers by Professor Oliver Lodge:—

10. *On Experiments illustrating Clerk Maxwell's Theory of Light.*
By Professor OLIVER LODGE, *F.R.S.*

11. *On an Electrical Theory of Vision.*
By Professor OLIVER LODGE, *F.R.S.*

DEPARTMENT II.

12. *On the Velocity of the Cathode Rays.*
By Professor J. J. THOMSON, *F.R.S.*

13. *On a Ten-candle Lamp for use in Photometry.*
By A. VERNON HARCOURT, *M.A.*, *F.R.S.*

The author has in former years brought before this Section a burner consuming a mixture of air with pentane vapour, and lamps consuming pentane vapour, which gave a constant amount of light equal to that of an average standard candle.

When so small a light is used in the ordinary photometry of coal-gas, errors from defects in the adjustment of the photometer, or from slight haziness in the atmosphere of the testing-place, are greater than when a light is used more nearly of the same magnitude as that of the gas-flame which is measured. A light of ten candles is well suited for the purpose. It has been shown that such a light can be obtained from an argand gas-burner consuming air saturated with the vapour of pentane; and a gas-burner has been proposed for use which is well suited for this purpose, except perhaps in being of a rather complex structure. But to supply air saturated with pentane vapour at a steady pressure there is needed a gas-holder of a few cubic feet capacity. The addition of such a gas-holder to the apparatus makes it more costly and not easily portable. It has been shown that great variations may occur in the proportions of pentane and air consumed by the gas-burner without materially affecting the light given out by the lower part of the gas-flame. The admixture of air is, however, unnecessary, since at a moderate temperature pentane can be volatilised without there being any necessity for reducing the atmospheric pressure by the admixture of another gas. The lamp shown is on the same principle as the one-candle lamp devised by the author seven years ago. The wick is raised or depressed by the ordinary rack-and-pinion movement, the lower end of it dipping into pentane in the body of the lamp, while the upper end is warmed by the heat conducted down from the flame. In the ten-candle burner the wick fills the circular interspace between the central and outer tubes of an argand. The only difference between this and an ordinary lamp is that the wick does not come near the flame, and needs no cutting or renewal; nor does the smoothness or roughness of its upper surface affect the burning of the lamp.

The dimensions of the lamp and chimney upon which the air currents inside and outside the flame depend have been determined by experiment so as to produce a bright and steady flame. The entrance to the inner tube is through a triangular opening as in the usual construction of such lamps. It was found that the free admission of air at this entrance caused an inequality in the flame, two peaks appearing on either side of the place of admission of air. To steady and regulate the admission of air at this point, a cylindrical case is fixed round the lower part of the tube, into which air is admitted through a round hole 15 mm. in diameter.

The flame of a rich gas burning from a wide opening is of the colour of candle-light even when an abundant supply of air is provided on both sides of the flame. The light of a good gas-burner is less red, or more blue, than this; and it is important for the photometry of coal-gas that the standard light employed should be as nearly as possible of the same colour as the light of the gas-flame. The light of the lamp has been brought to this colour by a small admission of air below the point of combustion. Twelve holes, each 3 mm. in diameter, have been drilled through the outer tube 15 mm. below the top. The draught of the chimney is sufficient to determine an entry of air through these holes, which, happening under fixed conditions, is constant in amount. A short cylindrical screen goes round the chimney, the bottom of which is 58 mm. above the surface of the burner; and both screen and chimney are surrounded by a pentagonal shade, four panels of which are filled with blue glass, while the fifth, which is turned towards the disc of the photometer, is filled half-way down with a metal plate, which, overlapping the inner screen, allows only the light from the lower part of the flame to fall on the disc of the photometer. By supporting the lamp at such a height that the bottom of the screen is level with the centre of the disc, errors of parallax are avoided. Mr. Sugg, I believe, observed, and Mr. Dibdin has proved, that with the flame of an argand burner the light thus given by the lower part of the flame is independent, within wide limits, of the total height of the flame. The observation is true, not only for a particular burner, but for many, and probably for most, argand burners. Many alterations have been made in the structure of this lamp, and it has generally been found, though not always with equal exactness, that the height of the flame did not affect the light emitted from its lower part. As the lamp is now arranged the height of the flame can be observed through the blue glass panels, and whether the top is just visible above the circular screen or rises to the top of the panel, the light which falls upon the disc of the photometer does not alter measurably. The adjustment of the light to the value of ten candles—in other words, the adjustment of the height of the circular screen—has been effected by a number of comparisons between the lamp and the one-candle pentane standard.

14. *On the Cause of the Spurious Double Lines sometimes seen with Spectroscopes, and of the Slender Appendages which accompany them.* By G. Johnstone Stoney, *M.A.*, *D.Sc.*, *F.R.S.*

Spurious double lines are sometimes seen with the spectroscope. In order to observe the phenomenon it is not necessary to use the complete spectroscope, nor is monochromatic light essential. It is sufficient to look with the telescope of the instrument directly down the collimator, so as to see the image of the slit. If the instrument be now pointed towards, or nearly towards, a distant flame, and if the slit be narrowed down to a certain point, a spurious double line will be seen in the observing telescope, instead of a correct image of the slit. The phenomenon will be produced under the circumstances which most readily admit of investigation when the incident light is restricted to a single beam of plane waves, falling on the slit either normally or obliquely; and incident light which sufficiently approximates to being of this kind is easily provided by placing a coarse supplementary slit in front of the lamp flame and allowing only the light which passes through this slit to reach the collimator.

Under these circumstances it will be found that when the light falls normally on the slit of the spectroscope it will form an image in the observing telescope which, with a certain width of slit, becomes a rather coarse double line bordered on either side by an exceedingly fine hair-like appendage, which is visible only when the light is sufficiently intense. By causing the incident light to fall obliquely the two constituents of the double line may be made to thin down, leaving a considerable dark interval between them, and then present very much the appearance of the sodium lines when fine. In intermediate positions of the incident light the interval between the two constituents of the double line is occupied by a bright ruling of hair-like appendages, varying in number with the inclination of the incident light. The conditions of the experiment may be modified in other ways, and other appearances produced—notably a flare consisting of a ruling of bright lines fading out in one direction.

All these appearances belong to the same class as the spurious disk of a star with its attendant diffraction rings when viewed through a telescope, and as the images which very minute objects present when examined by the microscope. In all these cases the image, as was long ago pointed out by Fraunhofer, is not a reproduction of the object. In fact, when the object is so small or so remote that the rays of light that reach the collimating lens from different parts of it differ only by a part of a wave-length or by a few wave-lengths, the diffraction phenomena which are always present become of large size. These, in the cases we have to deal with, take the form of a direct beam of light spread out, with coloured fringes extending like a fan to the right and left. If the telescope with which the object is viewed can take in the whole of these we get a true delineation of the object. But if it can only take in some of them, then the image we see is not a representation of the object, but the image of another object, viz. of that object which would emit the same central beam and those only of the fringes which the instrument can grasp, but not any of the others. In all cases this apparent object differs from the real object, and in some cases is wholly unlike it.

If, for example, after removing the eye-piece, we look directly at the light transmitted by the collimating lens, and make the adjustments such that the instrument takes in only the central beam and the first diffraction spectrum on either side, then on replacing the eye-piece we shall see a double line instead of a correct image of the slit. This, with some very thin appendages which can only be seen when the light is sufficiently bright, is, in fact, the kind of object which would emit a central beam and a first diffraction spectrum, and these only, of those breadths, in those phases, and with that ratio of the brightness of the central beam to the first diffraction spectrum which prevail between those parts of the light as actually received by the collimating lens.

The image that presents itself might conceivably be calculated by dividing the wave front as it passes the collimating lens into pairs of strips, and integrating the illumination these produce on the focal plane. This is the method employed in the case of the spurious disks of stars. But even if this method were practicable it would be inferior to a tentative geometrical treatment of the problem which, though it does not furnish the exact result, is more instructive. The geometrical method makes clear, which the integrations would not, why the thin appendage lines present themselves in addition to the main double line.

It was obviously desirable to attack the problem in its simplest form, which occurs when the incident light reaches the slit of the collimator normally. It is possible from general considerations, based on the theory of diffraction gratings, to conclude that then the main part of the light of the image as seen must be concentrated into *two* parallel strips constituting a so-called double line. The next step is to assume a distribution of light in two such strips which would produce, and which therefore would be the image formed by, a central beam and diffraction spectra of which those of even orders, the 2nd, 4th, &c., are of zero illumination. This can be done in various ways, producing different distributions of the light between the central beam and the spectra of odd orders. The next step is to select among these one which gives nearly the same ratio of brightness of the first spectrum to the central beam as prevails in the light which actually reaches the collimator from the slit. This was effected by making the strips broad, brighter in the middle, and with an interval between them about one-seventh of their width. The next step is to modify this distribution of light, so as to secure zero illumination in the third spectrum, while retaining the extinction of the spectra of even orders. This was effected by removing one-eighth of the light from each of the two strips; transferring half of this eighth to a certain part of the other strip, and with the other half forming an appendage line outside the strip, at a distance from it of nearly half its width, and only one-seventh as broad. The distribution of light, when modified in this way, on both the constituents of the double line would present the appearance of a somewhat coarse double line, with a narrow interval between them, and accompanied by two hair-like appendage lines, one to the right and the other to the left of the main double line; and this resembles the image as it actually presents itself in the telescope of the instrument.

We thus see that part of the light must appear in the form of faint appendages *in order to reconcile the extinction of the third spectrum with the simultaneous disappearance of the spectra of even orders.* To get rid of the distant and fainter 5th, 7th, &c., spectra consistently with the other conditions of the problem in general requires a further modification of the main lines, a modification of the appendages already existing, and the introduction of other still fainter appendages. It should be mentioned that it is possible to make the adjustments such that the appendage lines, or some of them, shall overlie the main lines, and become merged in them, so as not in the observations to be distinguishable from them.

Having, by the geometrical treatment of some simple cases, made ourselves acquainted with the general progress of events, it is best to study by observation what the details become with each of the innumerable distributions of light that can be made to pass the collimating lens, and to record the principal results; for it would be an endless task to attempt the prediction of every phase of so Protean a phenomenon. The observations are of a simple kind, since the image which is formed in each case may be directly viewed in the telescope, and we can also easily ascertain what has been the light that has produced this image, by simply taking out the eye-piece and then looking down the tube of the telescope and through its object-glass. We thus see the collimating lens, and those parts of the central band and diffraction fringes formed by the slit which have reached the collimating lens, so that these become known.

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15. *On the Luminosity observed when a Vacuum Bulb is broken.*

By JOHN BURKE.

It was noticed by Beccaria that a luminous effect was produced when vacuum bulbs were broken in the dark. After making some experiments upon the subject he attributed the luminous appearance, not to the breaking of the glass, but to the dashing of the external air, on the inside, when it was broken. Professor J. J. Thomson, in his work on 'Recent Researches in Electricity and Magnetism,' has brought forward the phenomenon observed by Beccaria as likely to confirm Mr. Crookes's theory of phosphorescence in a vacuum tube. The two phenomena, however, that of phosphorescence in a vacuum tube and that produced by the breaking of vacuum bulbs, seem to be totally distinct; and the luminosity in the latter case seems to be due to the collisions of the particles of glass with each other. Beccaria also obtained a light when air was allowed to strike against bodies placed inside a receiver, by the bursting of a bladder, but this was undoubtedly due to the burning portions of the bladder, that were stopped in their descent by the articles within the receiver, which he appears not to have observed.

The following experiments tend to disprove Beccaria's theory. A number of fragments of broken glass were supported at the mouth of the receiver of an air-pump by an arrangement such that when air was allowed to rush into the receiver by the removal of a thick glass plate which served to cover the opening at the top, the pieces of glass were capable of descending with the air. The same luminous effect was obtained as when vacuum bulbs were broken.

A single spark was visible when only one piece of glass was employed, and appeared as though it had been caused by the striking of this against the side of the receiver. When no fragments of glass were employed no light was observed, even when a number of articles were placed at the bottom of the receiver.

Air was made to issue forth, on the surface of various substances, and especially on the sharp edges of broken glass, from bottles containing the air in a highly compressed state, but without any luminous effect.

The same results were obtained with other gases besides air.

A light was obtained when two large pieces of glass were violently struck, but no light was observed by the mere breaking of glass either in air or in a vacuum.

Other substances instead of glass were also employed, such as cast iron, steel, copper, ebonite, sealing-wax, bone, but without any luminous effect.

All the experiments made seem to point to the conclusion that the phenomenon is not due to the violent impact of the air on the glass but to the collisions of the fragments of glass with each other.

16. *On the Correction of Optical Instruments for Individual Eyes.*
By TEMPEST ANDERSON, *M.D.*, *B.Sc.*

The subject of astigmatism is now well understood, and the public are beginning to recognise that a very large proportion of cases of defective sight require a cylindrical as well as a spherical element in the corrective spectacles, and can by this means obtain a much greater acuteness of vision than without it. It is also well known that ordinary myopic or hypermetropic eyes, even if presbyopic, can obtain perfect vision with a telescope or microscope by adjusting the focus; but it is quite different with astigmatic eyes, for as the image comes into focus with one meridian of the eye, it goes out with the other.

Persons with such eyes when ordered spectacles are often rather casually told that they must wear their glasses when using a telescope or microscope, but there the matter usually ends, for the spectacle glass is found to come against the eye-piece, and even if it does not, the spectacle lens is not centred on the instrument, and various ghosts and false images are formed, which cause the glasses to be laid aside.

Few eyes are altogether free from astigmatism; probably half could have their vision perceptibly improved by suitable cylindrical lenses; and though the defect is not sufficient to make it worth while to wear spectacles, it is greater than would be allowed to exist in a telescope or microscope by a good maker. The defect is, of course, more noticeable in the use of instruments which give a pencil of rays which fully fills the pupil, such as the lower powers of telescopes and opera glasses and hand-magnifiers.

The remedy is simple, viz., to mount a cylindrical lens of power suitable for the individual eye in a cap, which can be applied to the eye-piece of the instrument. The lens can be properly centred, and causes no ghosts or false images, and being close to the lens of the eye-piece takes up very little room, and allows the eye to come conveniently near the instrument. Each observer will have one lens to suit his own eyes, applied to his own instrument; but for the benefit of those who like a complete instrument with adjustments to suit their friends, I may point out that it is not necessary to correct the spherical error of the eye, as this can be done by focussing, so that a set of caps containing, say, a dozen cylindrical lenses of the ordinary powers would enable a telescope to be corrected for almost any observer, provided he knew what cylinder he required.

17. *How the Misuse of the Word 'Force,' in Attractions, Electricity, and Magnetism, may be avoided without much departure from existing practice.* *By* Dr. G. JOHNSTONE STONEY, *F.R.S.*

All the classical writers on dynamics of the early part of the present century—Laplace, Lagrange, Poisson, Gauss, and many others—used the word Force in two distinct senses, viz., for F the 'Moving force,' and for f the 'Accelerating force.' A distinct improvement was introduced several years ago when the word *force* was restricted to the former of these meanings, and when the 'accelerating force' was named the *acceleration*, or, as it ought rather to be called, the *accelerator*.

There is, however, one exception. In treatises on Attractions it is still usual to call f the *force* of attraction. There seems no sufficient excuse for this; and it is therefore suggested that the word *accelerator* be used instead. We may then say in dealing, for instance, with gravitation—

[Old names]	$f = -\mu \frac{M}{r^2}$ is the Accelerating force	$F = -\mu \frac{Mm}{r^2}$ is the Moving force
[New names]	Accelerator (often miscalled 'Force of attraction')	Force

Next as regards Potential. This term is used in Dynamics, Electricity, and Magnetism to designate physical quantities of different dimensions; but in all it is that factor of energy which, in order to convert it into energy, requires to be multiplied—

In Dynamics, by a mass.
In Electricity, by a quantity of electricity.
In Magnetism, by a quantity of magnetism.

This may be stated conveniently by saying that—

In Dynamics, Potential is the *dynamic energy-factor*. In Electricity, Potential is the *electric energy-factor*. In Magnetism, Potential is the *magnetic energy-factor*.

Now a similar treatment of the term *accelerator* would at once carry out consistency in our nomenclature, would point attention to the true relation between these three sciences, and would free us from one part of the misuse of the word force which is now prevalent. If this suggestion be adopted, we shall speak of—

The dynamic accelerator, viz., that *force-factor* which requires to be multiplied by mass to convert it into a force;
The electric accelerator, viz., that *force-factor* which requires to be multiplied by a quantity of electricity to convert it into a force; and
The magnetic accelerator, viz., that *force-factor* which requires to be multiplied by a quantity of magnetism to convert it into a force.

And these terms will take the place of what are now miscalled the Electric Force in an Electric Field, and the Magnetic Force in a Magnetic Field; physical quantities which are in reality not forces at all, but force-factors.

There will then remain only one, but it is the greatest offender of them all, viz., Electro-motive Force—an abominable term, since it is not a force, nor even a force-factor. It is in reality an energy-factor. Why not substitute the term *Potency* or *Potential Range*, which would exactly describe what it is, and which would offer the additional convenience of enabling us to speak, not only of the Potency of a battery or dynamo, extending over the entire current from pole to pole, but also of the Potential Range of each piece of apparatus introduced into the circuit extending from the place where the current enters it to the place where it emerges? It is often convenient to be able to speak of this concisely and without periphrasis. The phrase *potency of a battery* seems the most appropriate one for indicating how much work the battery compels each unit of electricity that traverses the circuit to do. This is what the term ought to imply; and the term Potency does so without introducing a false analogy like the term Pressure which is sometimes used.

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18. *On a Nomenclature for very much Facilitating the Use of Systematic Measures.* *By* G. JOHNSTONE STONEY, *M.A.*, *D.Sc.*, *F.R.S.*

In this communication the author recommended certain prefixes and affixes, which he had been engaged for several years in testing, and which provide a means of avoiding periphrases and of speaking and thinking concisely about matters with which modern science has frequently to deal. The syllables suggested are—

Hyper-, *-ein*, *-et*, *-o-*, *-el*, and *-ane.*

The metric system of weights and measures furnishes a *complete* decimal series of lengths and masses, and of the physical quantities derivable from them, such as volume, density, &c.: *i.e.*, it presents us not only with the metre, the gram, the cubic metre, and so on, but also with all the decimal multiples and submultiples of each of these. Moreover, it only needs to use the mètric system with the *second* as our unit of time to have an equally complete series of every other physical quantity, such as density, velocity, force, and energy in dynamics, along with the various other physical magnitudes with which the sciences of electricity and magnetism are separately concerned.

Now C.G.S. units are one of the innumerable metric systems of systematic physical units thus placed at our disposal. This particular system is found to be inconvenient for use by practical men; which makes it desirable that they should be able on many occasions to avail themselves of other metric systems equally systematic and in closer relation to their work. This is the more to be recommended since the translation from any such system into the C.G.S. system, in which our best tables of physical units exist, or from the C.G.S. system into it, can by the proposed nomenclature be made so conspicuous as to be always certain and easy. The prefix *hyper-* and the affix *-ein* are designed to provide us with facilities for doing this.

Employing the word *weights* to designate the pieces of metal used with our balances, it may be stated to be the usual practice of engineers and physicists to measure forces by the gravitations of these weights, *i.e.*, by the downward forces exerted by them at the station where the experimenter works. Now the gravitations or downward forces of all *weights*, and therefore of the metric series—the gram weight and its decimal multiples and submultiples—vary slightly from one station on the earth's surface to another; while the *decimal series of systematic forces* (determined by the condition that they are the force which will produce an acceleration of a metre per sec. per sec. in a mass of a kilogram, along with the decimal multiples and submultiples of this force) is a system of forces quite independent of the place of observation, and therefore each of them maintains the same value over the whole universe. Here, then, we have two decimal series of forces—one the fixed series required in dynamical calculations, the other the gravitations or downward forces of the metric weights, convenient in experiments but depending for the amounts of these forces upon the situation where the experiment is made. Now it so happens that the theoretic forces are close to—about two per cent. more than—the laboratory forces; and hyper-, when prefixed to the name of a weight, is intended to signify the slight increase which has to be made in it to make its gravitation become equal to the adjoining theoretical force. Thus in the language of systematic measures the hektogram, kilogram, &c., are *masses*; but the hyper-hektogram, hyper-kilogram, and so on, are *forces*, viz., those forces of the systematic decimal series which are about two per cent. more than the gravitations of the hektogram, the kilogram, and the other metric weights. The prefix hyper- may accordingly be paraphrased into '$10/g$ times the gravitation of the weight whose mass is a —.' The coefficient $10/g$, which is indicated by hyper-, (in which g is gravity at the station where the experiment is made, expressed in metres per second per second), varies from 1·022 at the equator to 1·017 at the pole, and is about 1·019 in England;[1] or, with more exactness, an observer at

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[1] The following is a convenient formula for the unit of absolute force:—

The hyper-hektogram = the gravitation or downward force *in vacuo* of

$$(10197{\cdot}8 + 26 \cos 2\lambda + \frac{h}{306}) \text{ centigrams}$$

at latitude λ, and at the height of h metres above the sea.

Hence the hyper-hektogram to the nearest milligram

	Grams used as weights *in vacuo* and at level of sea.				
=	102·238	at the equator			
=	101·978	at the latitude of 45°			
=	101·920	,,	Greenwich, which is		51° 28′
=	101·903	,,	Dublin	,,	53° 20′
=	101·902	,,	Manchester	,,	53° 29′
=	101·892	,,	Belfast	,,	54° 36′
=	101·882	,,	Glasgow	,,	55° 51′
=	101·881	,,	Edinburgh	,,	55° 57′
=	101·718	at the poles,			

the extreme range, between the equator and the poles, being the gravitation of about half a gram (0·52 gram).

Manchester would have to put into one scale of his balance 101·902 gram weights (with small corrections for his height over the sea, and for the air displaced by the weights) in order to urge this scale downwards with precisely that force (the hyper-hektogram) which, if it acted on a mass of one kilogram, would generate in it an acceleration of one metre per second per second. This he would express by saying that the hyper-hektogram (that member of the series of decimal systematic forces which differs but little from the gravitation of a hektogram) is in reality the gravitation at Manchester of 101·902 gram weights, weighed *in vacuo* and at the level of the sea.

Another affix which will be found convenient is *-ein*, meaning 'unit of,' so that the forcein shall signify the unit of force, the massein the unit of mass, &c., which we happen at the time to be employing. Thus in the C.G.S. system

The massein is one gram;
The lengthein is one centimetre;
The timein is one second;

whence

The forcein is the C.G.S. dyne, which is one hyper-milligram, and
The energein is the C.G.S. erg, which is the hundred-thousandth part of one hyper-grammetre.

The dyne is far too small a unit of force for convenient use in the laboratory of the mechanician or even of the physicist. It is the gravitation of a tiny fragment of note-paper not more than about one-eighth of an inch square. And the erg, the unit of energy in C.G.S. measure, is still more preposterously small. The grammetre is already a small measure of energy, the hyper-grammetre is only about two per cent. more; *and the erg is the hundred-thousandth part of this small measure.*

Much better systems for practical use are the K.M.S. system and the M.M.S. system. The K.M.S. system, which is based on the kilogram metre and second, will be found the most convenient in the laboratory of the dynamical physicist. In this system—

The massein is one kilogram;
The lengthein is one metre; and
The timein is one second.

These are its fundamental units, whence are derived—

The velocitein of one metre per second, about an ordinary walking pace;
The densitein of one gram per litre, in which unit the maximum density of water is 1,000, and the density of standard air is 1·276;
The forcein of one hyper-hektogram, a measure of convenient amount; and
The energein of one hyper-hektogrammetre, which is equally convenient. The supply of this amount of energy per second is what electricians call a 'watt.'

To the engineer and to the electrician the M.M.S. system offers certain advantages over that just described; and either of them is immeasurably to be preferred

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To each of these add one milligram for every 30½ metres (100 British feet) that the station is above the sea, and add between 15 and 16 milligrams if the weights are used in air, and if they are brass weights.

The correction for latitude may be made with sufficient accuracy within the British Isles by allowing one centigram for every 1° 7′ that the station is north of the latitude of 45°, *i.e.*, one milligram for a difference in latitude of 6·7 minutes of arc; the error of this approximation amounting to only one milligram at Edinburgh, where it is more than at any other of the above stations—an error which is usually of no account, since no determination of the kind can be made to within less than a fifthet of its entire amount.

in practical work to the C.G.S. system. In the M.M.S. system the fundamental units are—

A massein of ten kilograms (the myriagram);
A lengthein of one metre; and
A timein of one second;

whence we obtain, as derived units—

The velocitein = one metre per second;
The densitein = ten grams per litre, in which unit the maximum density of water is 100;
The forcein = one hyper-kilogram; and
The energein = one hyper-kilogrammetre.

Inasmuch as the engineer, if he uses metric weights, determines all his forces in kilograms and measures energy in kilogrammetres, the M.M.S. system is the most convenient for him. He has only to increase each of these measures by 1·9 per cent. to have his determinations expressed in hyper-kilograms and hyper-kilogrammetres, *i.e.*, in systematic measures adapted to any dynamical calculation he may have occasion to make. It is also deserving of note that this system is more conveniently related than the K.M.S. system to the C.G.S. system, in which our best tables have been computed. This arises from the circumstance that $\sqrt{LM}$, a physical quantity which is constantly turning up in the dimensional equations of electricity and magnetism, is in the M.M.S. system an exact decimal multiple of what it is in the C.G.S. system. The relation here pointed out is of importance to the electrician.

The use of the prefix hyper- has the additional advantage of keeping steadily before the mind of the student the actual amounts of the measures of force and energy with which he is dealing, and thus helps him to make his conceptions correspond to the facts of nature. The amount of each measure is not brought into view by such names as dyne and erg unless supplemented by such names as hyper-milligram and hyper-fifthet-grammetre, and is apt to be lost sight of in using the C.G.S. system.

The author was a member of the Committee of the British Association, which in 1873 recommended C.G.S. measures for general adoption by physicists. He put forward in competition with it the K.M.S. system, spoken of above, and also advocated the use of the prefix hyper- to be employed as described in this paper. It is correctly recorded in Everett's 'Units and Physical Constants' that he dissented from the choice made by the Committee, but the reason for his dissent is not correctly indicated. His main objection was that this choice *needlessly led to such out of the way values for the dyne and erg*—needlessly, because other choices might have been made, such as of either the K.M.S. or the M.M.S. system, which, while equally adapted to the sciences of electricity and magnetism, would have been free from this great inconvenience in dynamics. He regrets to have observed that the choice that was then made has retarded the use of systematic measures by practical men and even by students, and hopes that this may in some degree be remedied by the suggestions made in the present paper.

Another useful suffix is *-et*, meaning decimal submultiple. As applied to numerals it gives us such suitable names as sixthet, tenthet, seventeenthet for a unit in the sixth, tenth, and seventeenth places of decimals, which are otherwise expressed as 10^{-6}, 10^{-10}, 10^{-17}. A convenient symbolical representation is VI^{c}, X^{c}, XVII^{c}, the symbol ^{c} being very easily written and being what in Sir Isaac Pitman's system of shorthand spells *thet*, so that VI^{c}, X^{c}, XVII^{c} are to be read sixthet, tenthet, seventeenthet.

The suffix -et may also be appended to the names of measures, *e.g.*, metrets are the decimal subdivisions of the metre. These in their order are to be spoken of as the decimetre; the centimetre; the millimetre; the IV^{c}m, the fourthet-metre, or fourth metret; the V^{c}m, fifthet-metre, or fifth metret; and so on. Thus the micron used by microscopists may be described either as

.. The sixth metret or as
(0·b. The sixthet-metre,

this last being an abbreviated form of 'sixthet of a metre,' just as half-ounce and quarter-inch mean the same as half of an ounce and quarter of an inch. Similarly the measure in which wave-lengths of light are usually measured may be described indifferently as

The tenth metret or as
The tenthet-metre.

Either of these is to be preferred to the designation tenth-metre, which the author suggested many years ago,[1] and which has since been in some degree used. Either tenth-metret or tenthet-metre is correct, but the author himself prefers the latter form.

In the same way gramets are the decimal subdivisions of the gram. As an example of their use, it is possible by the kinetic theory of gases to arrive at an estimate of the mass of a single chemical atom of each element. That of hydrogen proves to be about the XXV‘*g*—the twenty-fifth gramet, or twenty-fifthet of a gram, *i.e.*, the twenty-fifth of that descending decimal series of which the decigram, the centigram, and milligram are the first three terms.

For multiples it is convenient to introduce the syllable *-o-*: thus, in the case of numbers, the name uno-eighteen will mean 10^{18}, the number which as ordinarily written would be 1 with eighteen ciphers after it. (This is about the number of molecules in each cubic millimetre of air at the bottom of our atmosphere.) The above number may be symbolised by XVIII, and so on in other cases. Again, this affix may be appended to such words as metre, gram, &c. Thus the velocity of light *in vacuo* is to be written 3mVIII/sec., and is to be read 'three metro-eights per second.' In like manner a tonne weight (the metric ton) is the gramo-six, and so on.[2]

Other useful affixes are *-el* and *-ane*: *-el* to be applied to British measures of length, *-ane* to metric. An accordance between British and metric measures of length may be brought about in either of two ways—either by slightly shortening the British inch, foot, and yard, or else by in an equal degree lengthening the metre. In the one case the British foot is shortened down to be exactly 30 centimetres, in the other case the metre is lengthened out to be exactly 40 inches. The syllable *-el* may be used to indicate the change required in the yard, foot, and inch. Accordingly the words inchel, footel, and yardel will mean the inch, foot, and yard *shortened* in the ratio of 63½ : 62½, or, which is the same thing, in the ratio of 101·6 to 100. On the other hand, the syllable *-ane* may be used to signify an equal change in the opposite direction of metric measures, so that the metrane, decimetrane, centimetrane, and millimetrane are to be understood as the metric measures *lengthened* in the same ratio, *i.e.*, as 62½ : 63½. With this convention as to the meaning of the affixes we may write—

one inchel = 25 millimetres,
one footel = 30 centimetres,
one yardel = 9 decimetres,
= $(1 - \frac{1}{10})$ metre;

and again—

one inch = 25 millimetranes,
one foot = 30 centimetranes
one yard = 9 decimetranes,
= $(1 - \frac{1}{10})$ metrane.[3]

(Light *in vacuo* advances almost exactly one footel in each ninthet of a second of time.)

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[1] *Phil. Mag.* for August 1868, p. 138.

[2] It would, no doubt, be more in consonance with the genius of the English language to call these the eighteenth uno, the eighth metro, the sixth gramo, and so on; but this consideration seems more than balanced by the great advantage possessed by the names as given in the text, of distinguishing in the broadest possible way between multiples and submultiples.

[3] The numbers we should otherwise have to use are: inch = 25·4 mm., foot = 30·48 cm., yard = 9·144 dm.

The use of these equivalents makes it easy for persons who are accustomed to the British yard, foot, and inch to think also in metric measures. They also furnish a link between British and metric measures which yields a ready means of effecting a closely approximate conversion of either into the other. For example, if we want to convert 27 yards into metres we write—

$$
\begin{aligned}
27 \text{ yards} &= (1 - \tfrac{1}{10}) \times 27 \text{ metranes} \\
&= \left\{ \begin{array}{r} 27 \\ -\ 2{\cdot}7 \end{array} \right. \\
&= 24{\cdot}3 \text{ metranes.}
\end{aligned}
$$

The correction of 1 in every 62·5 (which is the same as ·1 in every 6¼, or as ·02 in every 1¼) requires the addition of rather less than

$$\text{which gives} \qquad \begin{array}{r} +\ {\cdot}4 \\ \hline 24{\cdot}7 \end{array} \text{ metres}$$

as the approximate equivalent. The accurate value differs from this by less than half an inch, and, moreover, by continuing the process two steps further the accurate value may always be got out. The calculation is of a kind which, when one is accustomed to it, can be made in the head rapidly and with ease.

Department III.

1. *Report of the Electrical Standards Committee.*—See Reports, p. 117.

2. *Determination of the International Ohm in Absolute Measure.*
By Professor Viriamu Jones, *F.R.S.*—See Reports, p. 123.

3. *Comparison with the B.A. Units of some Coils of Low Resistance.*
By R. T. Glazebrook, *F.R.S.*—See Reports, p. 128.

4. *Comparison of the Standards of the Board of Trade with the B.A. Unit.*
By J. Rennie.—See Reports, p. 130.

5. *Comparison of some Standards belonging to the Indian Government.*
By E. O. Walker.—See Reports, p. 131.

6. *On the Specific Resistances of Copper and Silver.*
By Rev. T. C. Fitzpatrick.—See Reports, p. 131.

7. *On Standards of Low Electrical Resistance.*
By Professor Viriamu Jones, *F.R.S.*

8. *On the Specific Conductivity of Copper.* *By* J. Teichmüller.

WEDNESDAY, AUGUST 15.

The following Papers were read:—

1. *On the Displacements of the Rotational Axis of the Earth. By* Professor W. FÖRSTER.—This Paper was ordered by the General Committee to be printed *in extenso*. See Reports, p. 476.

2. *A Lecture-room Experiment to illustrate Babinet's Principle. By* Professor A. CORNU, *F.R.S.*—This Paper was ordered by the General Committee to be printed *in extenso*. See Reports, p. 480.

3. *A New Explanation of the Wave-movements of a Stretched String.*
By WM. BARLOW.

The writer begins by setting out the commonly received explanation which attributes to the string when disturbed the properties of a cord slipping through a bent tube at a velocity such as to make the pressure on the tube arising from the centrifugal force just balance the pressure caused by the tension.[1]

He then argues that this course involves the fallacy that a wave-movement is supposed to take place spontaneously in the disturbed cord, whereas all that the argument offered proves is that *if a wave is set up* and travels at a certain rate in a given direction, *it will have a constant form.*

He further shows that the conditions laid down do not suffice to determine the direction of the wave; that the direction is perfectly arbitrary.

He then suggests another explanation of the wave-movements in question.

This is based on the observed behaviour of a highly elastic cord, and he attributed the wave-movement to the successive orientation of segments of the stretched string caused by a difference of tension due to inertia, the spot at which the difference makes itself felt travelling along the string, now in one direction, now in the opposite, as the string swings from side to side of its normal position.

5. *On Lunar Curves of Mean Temperature at Greenwich, and the Heat of the Moon. By* J. PARK HARRISON.

The great heat experienced in 1893 led the author to tabulate the mean temperatures of the day at Greenwich for that year, according to the age of the moon, to see how far a curve derived from them corresponded with the model curve for 618 lunations, which was exhibited by him on the last occasion when the British Association visited Oxford. Whilst closely following the curve alluded to, the maximum temperature showed itself two days earlier in the lunation; but the same abrupt fall in temperature occurred immediately after the first quarter, and continued below the average of the year from that period until the second day after last quarter. The difference between the maximum on the fourth day of the lunation and the minimum on the day of full moon was 6° Fahr. for twelve complete lunations.

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[1] See Art. 'Wave,' *Enc. Brit.*, p. 416.

SECTION B.—CHEMICAL SCIENCE.

PRESIDENT OF THE SECTION—Professor HAROLD B. DIXON, M.A., F.R.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

'*An Oxford School of Chemists.*'

IT has been said, and no doubt with truth, that few Presidents of Sections start writing an address without referring to that of their predecessor who held office on the last occasion when the Association met in the same city. By such reference each new President gains the advantage of many points of perspective and contrast; for in the interval a generation of workers has passed away, and the last new thing of the old meeting is the ancient instance of to-day. In the present case I turned to the Report of 1860 with a lively hope of drawing inspiration from it; for my predecessor at the last Oxford meeting was no less a master of experiment and expression than the late Professor Brodie. Judge of my disappointment when I found that Brodie had written no address at all. Whether that great man, knowing there were better things to do here than listen to addresses, had the courage to make an innovation he thought desirable in itself, or whether, as others say, he was but obeying the etiquette of the Oxford professoriate, the fact remains, the assembled chemists went away unaddressed, and the natural spring of inspiration for the address of 1894 is found dry at its source. Of course you will say, 'Why do you not follow such a good example?' I wish I had the courage. As it is, I can but urge the vacuum of 1860 as some excuse for the emptiness of the address I now present—compelled to do so partly by the force of fashion and the demands of the assistant general secretary, and (shall I add?) partly by the gratification of holding forth, with a little brief authority, in my old academic home, endeared to me personally by so many happy memories, and hallowed in the minds of chemists by the traditions of such great achievements in the science we pursue.

I say *traditions* advisedly, for the chemical achievements spoken of were largely forgotten, or put on one side as guesses and half-truths. No chemist here will need reminding that I refer to *the first school of scientific chemistry*, the school founded two centuries and a half ago by Robert Boyle with his disciples Hooke and Mayow —a group whom I will venture to call 'the Oxford school of chemists.' And now that chemists are met together once more in Oxford it seemed to me not inappropriate for us to consider what this school of chemists accomplished, and wherein it failed, what led to the sudden growth and what to the decline of chemical investigation here, and what lessons for modern Oxford may be read in the history of that rise and fall.

The intellectual awakening which followed the re-discovery of the ancient world of literature gave rise to the scientific interrogation of nature. In Italy first, and then in France, England, and in Germany, the diffusion of classical learning broke down the ancient barriers of restraint, and developed a spirit of free inquiry. It was not so much that ignorance had to be dispelled, but that the right of search had to be established. Here and there during the Middle Ages some man of genius had arisen—learned beyond all his contemporaries, intrepid in the pursuit of truth—only to be crushed by a political and mental despotism. The name of Roger Bacon arises at once in our thoughts, who from his Oxford cell sent forth that great appeal for experimental science that nearly converted a Pope of Rome and won three centuries for intellectual freedom. But his labour bore no fruit. I know no better index to the dominant sentiment of the time than the following words from a papal rescript reproving the members of an Italian university for scientific presumption: 'They must be content with the landmarks of science already fixed by their fathers, and have due fear of the curse pronounced against him who removeth his neighbour's landmark.' Under such conditions no wonder philosophy was at a standstill. 'The same knots were tied and untied; the same clouds were formed and dissipated.'[1] The cramped philosophy of the Middle Ages had in alchemy a fitting colleague—with its mysticism, its sordid ideals, its trickery, and its arrogance. The revival of learning was thus an emancipation of the mind, and in the new freedom the sciences of mechanics, physics, and chemistry arose. The first necessity for progress was enlightenment, the second was experiment: in the year that Francis Bacon died Robert Boyle was born.

The common pursuit of experimental inquiry and the need for constant criticism and discussion among its followers led to the foundation of scientific societies. Such societies, which have greatly influenced the progress of knowledge, sprang up in Florence and Padua, in Paris and Oxford—wherever, among bodies of learned men, some were found in sympathy with natural philosophy. Among these associations the Philosophical Society of Oxford has played no unimportant part, and, however much Oxford may have undervalued its work, for one thing all chemists are grateful, and Oxford herself may feel proud—that here, under her influence, first grew up the idea that chemistry was no mere drudge of medicine, or genii of the alchemist, but a science to be studied purely for itself.

The origin of this Oxford Society has been well told by Dr. Wallis, one of its founders:—

'About the year 1645, while I lived in London (at a time when, by our civil wars, academic studies were much interrupted at both Universities), besides the conversation of eminent divines, I had the opportunity of being acquainted with divers worthy persons inquisitive into natural philosophy, and particularly of what hath been called experimental philosophy. We did by agreements meet weekly in London to treat and discourse of such affairs; of which number were Dr. John Wilkins, Dr. Jonathan Goddard, Dr. Ent, Dr. Merret, Mr. Samuel Foster, then Professor of Astronomy in Gresham College, and Mr. Theodore Haak, and many others.

'These meetings we held sometimes at Dr. Goddard's lodgings, on occasion of his keeping an operator at his house for grinding glasses for telescopes and microscopes; sometimes at a convenient place in Cheapside, and sometimes at Gresham College. Our business was (precluding matters of theology and State affairs) to discourse and consider of philosophical inquiries. . . . About the year 1648, some of our company being removed to Oxford (first Dr. Wilkins, then I, and soon after Dr. Goddard), our company divided. Those in London continued to meet there as before, and those of us at Oxford, with Dr. Seth Ward (since Bishop of Salisbury), Dr. Ralph Bathurst, President of Trinity College, Dr Petty, Dr. Willis (an eminent physician in Oxford), and divers others, continued such meetings in Oxford, and brought those studies into fashion there, meeting first at Dr. Petty's lodgings (in an apothecarie's house), because of the convenience of inspecting drugs, and, after his removal, at the lodgings of Dr. Wilkins, then Warden of Wadham College, and, after his removal, at the lodgings of the Honourable Mr. Robert Boyle, then resident for divers years in Oxford.'

Robert Boyle, the youngest child of the great Earl of Cork, was born at Lismore in 1626. His mother died when he was a child. Always delicate, he was sent at twelve years of age with a tutor to the Continent; he remained abroad for six years. He studied chiefly at Geneva and at Florence, where he read the works of Galileo. Returning to England in 1644, he busied himself with chemistry at Stalbridge, a manor in Dorsetshire left him by his father. On his visits to London he became one of the members of the 'Invisible College,' the germ of the Royal Society. 'Vulcan has so bewitched me,' he writes at the age of twenty-three, 'as to make me fancy my laboratory a kind of elysium.'

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[1] Whewell, *Hist. of Ind. Sci.*

Drawn to Oxford in 1654, Boyle spent here the most active years of his life in experimental research. Of Boyle's scientific writings much has been said in extravagant praise and much in ridicule. Boerhaave wrote: 'To him we owe the secrets of fire, air, water, animals, vegetables, and fossils.' This phrase is not more grotesque than that of a recent writer, who says, 'Boyle's name is identified with no great discovery.' Dr. Johnson has very justly remarked, in a number of the 'Rambler:' 'It is well known how much of our philosophy is derived from Boyle's discoveries, yet very few have read the details of his experiments. His name is indeed reverenced, but his works are neglected.' It is, indeed, rather hard to read through one of Boyle's papers, even in the abridged form. Though clear, they are discursive. The writer cannot rid himself entirely of the essences and qualities of the alchemists; and it is only when we compare these records with the works of Van Helmont, his immediate predecessor, that we recognise the enormous advance that has been made by Boyle. I must pass over his physical work on the elasticity of the air. It must suffice to say that he established by most careful experiment the law which is known by his name—that the volume of a given mass of air varies inversely as the pressure upon it. He determined the density of the air, and pointed out that bodies altered in weight according to the varying buoyancy of the atmosphere. One of his most important chemical papers—certainly the one most frequently cited—is 'The Sceptical Chemist,' published anonymously in 1661. I will attempt the briefest account of it. The opening words of the dialogue strike the keynote of the whole:—

'Notwithstanding the subtle reasonings of the Peripatetics and the pretty experiments of the Chymists, I am so diffident as to think that, if neither can produce more cogent arguments than are usually given, a man may reasonably doubt as to the number of those material ingredients of mixed bodies which some call elements and others principles.' He proceeds, through the mouth of one of the supposed disputants, to attack the doctrine of the three elements, the *tria prima* of the alchemists—sulphur, mercury, and salt. 'There are some bodies,' he says, 'from which it has not yet been made to appear that any degree of fire can separate either salt, or sulphur, or mercury, much less all the three. Gold is the most obvious instance. It may be heated for months in a furnace without losing weight or altering in character, and yet one of its supposed constituents is volatile and another combustible. Neither can water or solvents separate any of the three principles from gold; the metal may be *added to*, and so brought into solution and into crystalline compounds, but the gold particles are present all the time; and the metal may be reduced to the same weight of yellow, ponderous, malleable substance it was before its mixture.' He points out the confusion which earlier chemists had made between calcination in the open air and distillation in retorts; he shows that in compounds, *e.g.*, copper nitrate, the particles retain their nature, although disguised, in the combination, for the nitric acid may be separated by heat, the copper by precipitation. But the sceptical chemist, though pouring ridicule on the *tria prima*, could not but admit the power of water to produce organic substances. He quotes Van Helmont's famous experiment of growing a shoot of willow in baked earth moistened with distilled water, and he repeats the experiment in various forms. Ignorant of the existence of carbonic acid in the air (discovered a century later by Black), he is driven to conclude that the plant is fashioned out of the pure water. But he rejects the doctrine—as old as Thales and as modern as Van Helmont—that water is the foundation of all things. M. de Rochas had published a remarkable experiment on water. By artificial heat, by graduations of coagulations and congelations, he had turned it into earth which produced animals, vegetables, and minerals. The minerals began to grow and increase, and were composed of much salt, little sulphur, and less mercury; the animals moved and ate, and were composed of much sulphur, little mercury, and less salt. 'I have some suspicions,' says Boyle, 'concerning this strange relation; though, as for the generation of living creatures, both vegetable and sensitive, it need not seem incredible, since we find that our common water, which is often impregnated with a variety of seeds, long kept in a quiet place, will putrefy, and then, too, produce moss and little worms according to the nature of the seeds that were lurking in it.'

I will give two short quotations from the 'Sceptical Chemist,' which show the author at his best and his worst. In the first he is discussing the nature of chemical combination between elementary particles: 'There are clusters wherein the particles stick not so close together, but they may meet with corpuscles of another denomination, disposed to be more closely united with some of them than they were among themselves; and in such case two corpuscles thus combining, losing that shape, size, or motion upon whose account they exhibited such a determinate quality, each of them really ceases to be a corpuscle of the same denomination as it was before; and from the coalition of these there may result a new body, as really one as either of the corpuscles before they were confounded. . . If you dissolve minium in good spirit of vinegar and crystallise the solution, you shall not only have a saccharine salt exceedingly different from both its ingredients, but the union is so strict that the spirit of vinegar seems to be destroyed . . . for there is no sourness at all, but an admirable sweetness to be tasted in the concretion.' In this passage we can distinctly see the germ of the modern theory of chemical affinity uniting atoms into chemical compounds. In the second quotation Boyle is arguing that fire is not only an analyser of mixtures, but compounds the ingredients of bodies after a new manner; mercury, for instance, may be turned into a liquid, from which the mercury cannot be reduced again, and consequently is more than a 'disguise' of it. 'Two friends of mine,' he says, 'both of them persons of unsuspected credit, have solemnly assured me that after many trials they made to reduce mercury into water, they once, by several cohobations, reduced a pound of quicksilver into almost a pound of water, and this without the addition of any substance, but only by urging the mercury with a fire skilfully managed. Hence it appears that by means of fire we may obtain from a mixed body what did not pre-exist therein.' Boyle has sometimes been charged with credulity, and chemists who know how mercury has a way of disappearing without leaving even its weight of water behind will smile to hear that the persons of unsuspected credit responsible for this experiment were 'the one a physician, the other a distinguished mathematician.'

Boyle's writings contain the record of numerous important chemical observations, *e.g.*, the synthesis of nitre, and the preparation of nitric acid by the distillation of nitre with oil of vitriol. He discovered several of the delicate tests we still use, *e.g.*, solution of ammonia as a test for copper, silver nitrate as a test for chlorides, gallic acid as a test for iron. But I wish especially to refer to the work done by Boyle on the air and its relation to combustion. The air, according to him, was composed of three different kinds of particles: (1) exhalations from water and animals; (2) a very subtle emanation from the earth's magnetism, which produces the sensation of light; and (3) a fluid compressible and dilatable, having weight, and able to refract light. It is this third portion of air which plays an active part in many chemical operations. Like Van Helmont, Boyle recognised differences in gases, but did not distinguish them as being something different in kind from air. He prepared hydrogen by the action of hydrochloric and sulphuric acids on iron, but his chief concern was to show that the new gas was compressible and was dilatable by heat; in other words, that it was really *air*. His observations are worth quoting; they contain, I believe, the first undoubted description of hydrogen, and the first method devised for collecting and examining freshly prepared gases.

'Having provided a saline spirit . . . exceedingly sharp and piercing, we put into a viol a convenient quantity of filings of steel, purposely filed from a piece of good steel. This metalline powder being moistened with the menstruum was afterwards drenched with more, whereupon the mixture grew very hot, and belched up copious and stinking fumes. . . . Whencesover this stinking smoak proceeded, so inflammable was it, that upon the approach of a lighted candle it would readily enough take fire, and burn with a blewish and somewhat greenish flame at the mouth of the viol; and that, though with little light, yet with more strength than one would easily suspect.'[1]

And again: 'We took a clear glass vial, capable of containing three ounces of water, with a long cylindrical neck; this we filled with oil of vitriol, and fair water, of each a like quantity, and casting in six small iron nails we stopped the mouth of the glass, and speedily inverting it, we put the neck of it into a wide-mouthed glass with more of the same liquor in it. . . . And soon after we perceived the bubbles, produced by the action of the menstruum upon the metal, ascending in swarms; by degrees they depressed the liquor till, at length, the substance contained in these bubbles possessed the whole cavity of the vial. And for three or four days and nights together the cavity of the glass was possessed by the air, since by its spring it was able for so long a time to hinder the liquor from regaining its former place. Just before we took the vial out of the other glass, upon the application of the warm hand to the convex part of the glass, the imprisoned substance readily dilated itself like air, and broke through the liquor in several succeeding bubbles.'

The importance of this experiment will be evident when we consider that Van Helmont had declared that gases could be made artificially in many ways, but could not be caught and held in vessels.[2]

Armed with the air-pump which he had so greatly improved, Boyle in 1660 began many experiments on combustion, which he afterwards published under the title 'New Experiments touching the Relation betwixt Flame and Air.' In these researches he shows that sulphur will not burn when the air is removed. The sulphur was lowered on to a hot iron plate in a receiver made vacuous by the pump; it smoked, but did not ignite. On allowing a little air to enter 'divers little flashes could be seen:' these were extinguished on sucking out the air again. A candle flame and a hydrogen flame under a receiver were gradually extinguished when the air was pumped away. On the other hand, on dropping gunpowder on to a hot iron plate *in vacuo* there appeared 'a broad blue flame like that of brimstone, which lasted so very long we could not but wonder at it'; and fulminating gold detonated *in vacuo* when heated by a burning glass, or when dropped on heated iron. Gunpowder also he found to burn under water. He is driven to the conclusion 'that flame may exist without air.' But it may be supposed that air is mechanically enclosed in the crystals of nitre—'in its very formation the corpuscles may intercept store of little aereal particles. . . . According to this surmise, though our mixture burns under water, yet it does not burn without air, being supplied with enough to serve the turn by the numerous eruptions of the aereal particles of the dissipated nitre.' However, he 'removes this suspicion' by obtaining nitre crystallised *in vacuo*. He then suggests the possibility of the nitre supplying 'vehemently agitated vapours' which are no true air, but being exceedingly rarefied by the fire 'emulate air.' Boyle never grasped the true function of air in combustion. From his later experiments on the calcination of metals he drew the same conclusion that we find in the 'Sceptical Chemist,' namely, that igneous particles combine with other corpuscles to form new bodies. And yet he saw there was a real connection between air and fire. In his tract on Artificial Phosphori Boyle showed that a piece of phosphorus sealed up in a glass vessel gradually lost its light. 'It seems,' he wrote, 'that the air included with the phosphorus either had some vital substance preyed upon thereby, or else was tamed by the fumes of the phosphorus and rendered at length unfit to continue the particular flame of our noctiluca.'

The genius of Robert Hooke was in sharp contrast with that of Boyle.

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[1] 'On the Difficulty of preserving Flame without Air,' 1672.

[2] 'Gas, vasis incoercibile, foras in aerem prorumpit.'—*Ortus Medicinæ.* The epithet 'sylvestre' was applied by Van Helmont to all artificially prepared gases. He meant by it 'untameable' and 'non-condensible'—'quod in corpus cogi non potest visibile.'

Quick, restless, imaginative, he sprang from discovery to discovery. With extraordinary acuteness and powers of invention, he lacked the steady purpose of Boyle, the calm judgment and completeness of Newton—his two great scientific contemporaries. It might be said of Hooke, as was said of a great poet, he touched nothing he did not strike fire from; and some would add that his touch had the same effect on persons as on things. We can hardly name a discovery of this age which Hooke had not in part anticipated and claimed as his own. Like a prospector in a newly discovered mining district, he hurried from spot to spot, pegging in his claims and promising to return to work out the ore. And what rich lodes he struck! The particular claim we are concerned with here is the discovery of the relation between air and flame. In 1665 Hooke published in the 'Micrographia' a description of flame and the phenomena of combustion which in my judgment has never been surpassed. How far he was indebted to Boyle will appear directly.

Born in 1635, Hooke spent five years at Westminster School, then under Dr. Busby, and proceeded to Christ Church in 1653. At school and college it is related of him that he devoted his time to designing flying machines. These mechanical inventions attracted the notice of Dr. Wilkins, Warden of Wadham, and a leading member of the Philosophical Society. This led to his introduction to Dr. Willis, to whom he became assistant in chemistry and natural philosophy. Willis recommended him to Boyle, whose assistant he became. His first work in Boyle's laboratory was the construction of the improved air-pump. In 1662 Boyle obtained for him the position of curator of experiments in the London Society, soon to be known as the Royal Society. Hooke was thus Boyle's assistant when those experiments on combustion I have described were being carried on. Among other experiments made by Boyle were some on the distillation of wood in retorts.

'Having sometimes distilled such woods as box, whilst our *caput mortuum* [*i.e.*, the residue] remained in the retort it continued black like charcoal, though the retort were kept red hot in a vehement fire; but as soon as ever it was brought out of that vessel into the open air the burning coals would degenerate or fall asunder into pure white ashes.'[1] Hooke saw the experiment and a new light flashed on him. 'From the experiment of charring coals,' he writes, '(whereby we see that, notwithstanding the great heat, the solid parts of the wood remain, whilst they are preserved from the free access of the air, undissipated) we may learn that which has not been published or hinted, nay, not so much as thought of by any; and that in short is this:—

'That the air is the universal dissolvent of all sulphurous [*i.e.*, combustible] bodies. . . .

'That this action of dissolution produces a very great heat, and that which we call fire.

'That this action is performed with so great a violence, and does so rapidly agitate the smallest parts of the combustible matter, that it produces in the diaphanous medium of the air the action, or pulse of *Light*.

'That this dissolution is made by a substance inherent and mixed with the air, that is like, if not the very same with, that which is mixed in saltpetre.

'That the dissolving parts of the air are but few . . . whereas saltpetre is a menstruum . . . that abounds more with these dissolvent particles.

'It seems reasonable to think that there is no such thing as an element of fire, . . . but that that shining transient body which we call flame is nothing else but a mixture of air and volatile parts of combustible bodies, which are acting upon one another whilst they ascend; which action . . . does further rarifie those parts that are acting or are very near them, whereby they, growing very much lighter than the heavy parts of that *menstruum* that are more remote, are thereby protruded and driven upwards.'

Hooke quotes no other experiments in support of his theory of flame. He states that he has made many; he has, however, only time 'to hint an hypothesis,' which if he is permitted opportunity he will 'prosecute, improve," and publish.' Some years later he returned to the subject of flame in his tract called 'Lampas,' published in 1677. 'The flame, as I formerly proved, being nothing but the parts of the oyl rarified and raised by heat into the form of a vapour or smoak, the free air that encompasseth this vapour keepeth it into a cylindrical form, and by its dissolving property preyeth upon those parts of it that are outwards, . . . producing the light which we observe; but those parts which rise from the wick which are in the middle are not turned to shining flame till they rise towards the top of the cone, where the free air can reach and so dissolve them. With the help of a piece of glass anyone will plainly perceive that all the middle of the cone of flame neither shines nor burns, but only the outward superficies thereof that is contiguous to the free and unsatiated air.'

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[1] *The Sceptical Chemist.*

What is practically the same theory of flame was worked out experimentally by John Mayow, Fellow of All Souls: this was published a few years after the 'Micrographia.'

But Mayow went further, and distinctly showed the dual nature of the air. One constituent of air, the nitre air, is concerned in respiration and combustion; the other will neither support flame nor animal life. The ideas, the names, proposed by Hooke and Mayow are so exactly similar that it is impossible to imagine that the work was done independently. The two were working at the same time at Oxford, and Mayow, having been an undergraduate at Wadham under Dr. Wilkins, became the pupil of Willis. Yet Mayow nowhere mentions Hooke's name. A writer in the 'Dictionary of National Biography'[1] has shrewdly observed that Hooke has brought no charge of plagiarism against Mayow, and even proposed him for the Royal Society four years after the publication of the 'Five Tracts.' Knowing what we do of Hooke's jealousy, it seems exceedingly unlikely that Mayow was merely working out Hooke's ideas. It seems to me probable that Hooke and Mayow worked together under Boyle between 1660 and 1662; that in Boyle's laboratory they saw and assisted in the experiments which led them jointly to their theory; that Hooke, busy with other work in London, published the hypothesis in 1665 without further verification; and that Mayow in Oxford systematically worked through the experiments on which he based his conclusions.

Let me briefly show what the experiments were on which Mayow relied. Combustible bodies will not burn in the vacuous receiver of Boyle's air-pump; they will burn *in vacuo* or under water when mixed with nitre. There is, therefore, something common to air and to nitre which causes combustion. The fiery particles in air and in nitre both form oil of vitriol by their union with sulphur; they both form iron vitriol by their union with pyrites. Rust of iron is produced both by the air and by acid of nitre; the acids of sugar and honey are formed, and wine is soured, in the same way. The nitre-air (spiritus nitro-aereus), the supporter of combustion and the acid producer, is therefore the same chemical substance whether it exist in the gaseous form in air or is condensed in saltpetre.

Mayow heated a weighed quantity of antimony by means of a burning glass, and found it increased in weight during the calcination;[2] the calcined antimony, he adds, has the same properties as the body prepared by heating antimony with nitric acid; it is impossible to conceive, he says, whence the increase in weight arises except by the fixation of the particles of nitre-air during the heating.

The nitre-air does not make up the whole of the air, but only its more active and subtle part, for a candle under a glass will cease to burn while there is still plenty of air left. The experiment by which Mayow shows this is so important that I will quote his words:—

'Let a lighted candle be so placed in water that the burning wick shall rise about six fingers' breadth above the water; then let a glass vessel of sufficient height be inverted over the candle. Care must be taken that the surface of the water within the glass shall be equal in height to that without, which may be done by including one leg of a bent syphon within the vessel while the other opens outside. The object of the syphon is that the air, enclosed by the vessel and compressed by its immersion into the water, may escape through the hollow syphon. When the air ceases to issue, the syphon is immediately withdrawn, so that no air can afterwards get into the glass. In a short time you will see the water gradually rising into the vessel while the candle still burns.'

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[1] Mr. P. J. Hartog.

[2] This experiment seems to have been first described by Poppius, *Basilica Antimonii*, 1625.

In other experiments he burnt camphor and sulphur supported on a shelf in the inverted vessel. The water rose, he says, because, owing to the disappearance of the fire-air, the air left could not resist the pressure of the atmosphere outside. When the combustibles were extinguished it was impossible to kindle them again by means of the sun's rays concentrated on them by a burning glass. The residual air was no more able to support combustion than the vacuum of Boyle's engine. Again, the respiration of animals in the closed space was shown to diminish the air, and to render it incapable of supporting combustion; the fire-air was as necessary for life as for flame. The larger portion of the air was something entirely different from fire-air, and incapable of supporting life or combustion. I believe this to be the first definite statement founded on experiment that the air is composed of two distinct gases.

I have given the fundamental facts in chemistry we owe to Mayow; the limits of his work are sufficiently obvious. He detected the existence of what we call oxygen gas in the air, and demonstrated some of its most remarkable properties. He did not isolate the gas, or show what became of it in combustion; he did not always distinguish between the gas itself and the heat produced by its action. But the advance he made was extraordinary—not so much in the conclusions he drew as in the experiments and arguments he founded them on. Compare him for a moment with another writer who had previously expressed similar views concerning the calcination of metals. Jean Rey, of Perigourd, a witty and shrewd physician, published in 1630 a series of essays attributing the increase in weight of metals on calcination to the fixation of the air. 'When asked,' he writes, 'why tin and lead increase in weight on calcination, I reply and gloriously maintain that this increase comes from the air which is thickened and made heavy and adhesive by the long continued heat of the furnace. This air mingles with the calx and attaches itself to the smallest particles.' The reply is good, but the reasons that gloriously maintain it are not altogether conclusive. I can only give two of them: (1) *The air has weight.*—This is shown by the increase in velocity of heavy bodies falling to the earth, because as the body approaches the earth it subtends a wider angle from the centre of the earth, and receives more shocks from the particles of air. Again, although the air appears to weigh nothing on the balance, this is because we weigh it in air; it loses its weight, just as water weighs nothing in water. Fire has weight too, and should we ever find ourselves in a region where fire is the predominant element, we shall be able to prove the statement in the same way. (2) *Fire can thicken and make air heavy.*—Stand a cannon upright and put a red-hot ball into it. You must admit that the air in the gun is so small in quantity that it will be heated to the same temperature as the ball. Nevertheless you can hold your hand in the mouth of the gun at first, but in a short time you cannot do so. Not that the air has got hotter, it is cooling all the time; it is because the air is thickened. Now if you drop a fleece of wool into the mouth, it will not descend, and if you push it in, it will come up again, proving the air is heavier. Lastly the air is seen to tremble over the mouth of the gun, and objects seen through it are blurred. This is due to the thickening, it cannot be due to a motion of the air; 'for I see,' he says, 'a lady's beauty quite distinctly through the air she flutters with her fan.'

From what has been stated it will be clear that the Oxford School of Chemistry was a *school of research.* Boyle gave no instruction in the ordinary sense; and, indeed, had no official connection with the University. But that he thought instruction in chemistry should be given in the University is obvious from the fact that he brought over a chemist from Strasburg, and set him up as a lecturer with rooms next his own and the use of his laboratory. Of these lectures we find a quaint account in Anthony Wood's diary:—

'An. Dom. 1663.

'Began a course of chemistry under the noted chemist and rosicrucian, Peter Sthael, of Strasburgh, brought to Oxon. by the hon. Mr. Rob. Boyle, an. 1659. He took to him scholars in the house of John Cross next on the w. side to University Colle. The club consisted of 10 at least, whereof Francis Turner of New Coll. was one, Ben Woodroff of Ch. Ch. another, and John Lock of the same house, afterwards a noted writer. This John Lock was a man of turbulent spirit, clamorous and never contented. The club wrote and took notes from the mouth of their master, who sat at the upper end of the table, but the said J. Lock scorned to do it; so that while every man besides were writing, he would be prating and troublesome. After the beginning of the year 1663 Mr. Sthael removed his elaboratory to a draper's house, called John Bowell, afterwards mayor of the city, situate in the parish of All Saints. He built his elaboratory in an old hall in the back, for the house itself had been an ancient hostle; therein A. W. and his fellows were instructed. The chemical club concluded, A. W. paid Mr. Sthael 30 shill: having paid 30 shill: beforehand. A. W. got some knowledge and experience, but his mind still hung after antiquities and musick.'

In spite of Boyle's private position, his blameless life, his devoutness, and his charity, his work aroused bitter animosity in Oxford. He was attacked in the University pulpit, in public orations, in private squibs; his theories were described as destructive of religion, his experiments as undermining the University. But what chiefly drew the indignation of his opponents was that he, a gentleman by birth and fortune, should concern himself with low mechanical arts. Against these attacks Boyle replied with irresistible logic. His vindication of the nobility of scientific work constitutes one of his greatest claims on our gratitude.

Boyle left Oxford in 1668. Mayow died in 1679. In 1683 Anthony Wood informs us that 'the Oxford elaboratory was quite finished;' but the impulse given to the study of Chemistry in Oxford gradually died out. I do not know the history of the Chair of Chemistry in Oxford (if there was one) in the eighteenth century. Richard Frewin, of Christ Church, is described as Professor of Chemistry in 1708. He does not seem to have taken himself too seriously in this capacity. Uffenbach, who visited Oxford in 1710, says he found the stoves in fair condition, but everything else in the laboratory in dirt and disorder. Frewin himself was elected Camden Professor of Ancient History in 1727. He seems to have thrown himself into his new work with greater ardour; for Hearne relates that, on his election, he at once bought one hundred pounds' worth of books in chronology and history to fit himself for his duties. For a companion picture to this we may glance at the appointment in 1764 of Richard Watson (afterwards Bishop of Llandaff) to the Chair of Chemistry at Cambridge, which had been founded in 1702. Dr. Watson, we are told, knew nothing at all of chemistry; had never read a syllable nor seen a single experiment on the subject. On his election he sent to Paris for an 'operator,' and set to work in his laboratory. In fourteen months he began to lecture to a large audience.

But Watson at Cambridge was succeeded by Wollaston. We had to wait till Brodie for a successor to Boyle.

II.

We have seen what a vigorous effort Chemistry made to plant itself in Oxford in the seventeenth century. If the soil had been prepared the roots must have struck deep. But the University paid little heed, and after a few years of prodigal growth the plant withered and died out. It would seem that the positions are reversed at the present day. The University spends large sums for supervision and appliances; the young plants are brought here and nurtured at great expense, but the fair blossoms produce little fruit. Even our best friends admit that the results are somewhat disappointing. If these are the facts—and I speak as one who shares the responsibility for the present condition of chemistry here—it is the duty of those concerned to speak out; and I can conceive no more fitting opportunity than the present for pointing out some of the causes that appear to hinder our growth. Let no one think I wish to disparage the University. I should be the last person to do so. I owe to my old college the opportunity, the help, and the example which made me a chemist, and gave me an interest in life. I only wish to see more general the advantages it was my luck to meet with in Christ Church.

Chemistry in modern Oxford is accorded a place side by side with older studies. No one can complain that scholarships are not offered broadcast, that money has not been freely given for laboratories; and yet I think the student does not feel around him the atmosphere in which an experimental science should be cultivated. We see Chemistry endowed and extended, we do not see it respected by the bulk of students and of learned men. In my undergraduate days a rhyme was current here (I think it was coined in Cambridge—the Parnassus of parodies) expressing views which were undoubtedly held concerning the claims of chemistry as a subject for a degree. One verse ran—it was from the Lamentation of a would-be Bachelor—

'I thought to pass some time before, but here, alas, I am,
Having managed to be plucked in every classical exam.
I cannot get up Plato, so my reverend tutor thinks
I had better take up Chemistry, which is commonly called "Stinks."'

I do not quarrel with the versifier (except as a poet), I do not even quarrel with the reverend tutor, whose opinion of us is obviously small, because I do not think myself that Chemistry as it is taught is a very good subject for a degree. Still less is it a subject which we should allow to monopolise the schoolboy's time. While holding strongly that the elements of Physics and Chemistry form a necessary part of a liberal education, I believe we have made two mistakes with regard to the teaching of science. We have by our science scholarships encouraged too early specialisation at school; we have overburdened our undergraduates here with a multitude of facts they cannot retain. A boy specialises for two years at school; he learns a prodigious array of facts from the latest text-book, and also acquires some skill in the art of quickly reproducing what he has learnt. He wins a science scholarship. We then tell him he must go back to, or begin, the study of the classical languages we look on as essential for our degrees. By a certain time he must reach a certain (rather low) standard, or his scholarship lapses. He learns that it is advisable to get assistance from those who have made a special study of preparing candidates for pass examinations. He crams; or he goes to a crammer and is crammed. Let us suppose, as is usually the case, that the obstacle is Greek. I will not deny that the standard of Greek demanded may imply some important discipline at school, and some real culture of the mind, provided the instruction given is on wholesome lines and forms part of a liberal course. Got up in a hurry as it too often is, solely with the object of passing, it means time and effort wasted and worse than wasted. It is of no value in itself, for it is forgotten in less time than it took to acquire; and it gives the student the first pernicious taste of that superficiality and false knowledge it should be our special aim to remove. Is it not desirable that scholarships should be the reward of progress and ability *in the general subjects of school education* among which the elements of science should have a place? The brightest and most persevering boys would come to the University, and there make choice of the special course they wished to pursue.

My second complaint is that we teach too many facts. They are not all important. After three or four years' steady accumulation our men go into the schools walking dictionaries of chemistry. Parents not unnaturally think that their sons, after four years of college training, should be fit to take responsible places wherever chemists are in demand. But manufacturers, as a rule, do not care for University graduates. I cannot blame them. We cannot guarantee that the men we send out with honours in Chemistry can attack a new problem, can work out new processes, can prepare new dyes. German manufacturers, on the other hand, *prefer* a University graduate, for they have in *their* degree a guarantee that the student has successfully attacked some unknown problem, and added to the store of knowledge.

The influence of science on the nation's industry has been recognised and insisted on by those who can make their voices heard. The country has at length awakened to the fact that something is wanting, and cries out for Technical Instruction. It is not afraid of spending money: indeed, many well-meaning bodies are spending—and in some cases, I fear, wasting—money with a prodigal hand. And what, after all, is the great need? Speaking for the subject I know best, I say unhesitatingly that we want scientific chemists who can and will make discoveries; we want men trained, not only in what has been done, but taught how to set about winning new knowledge. The Universities, I urge, should teach the art of research. This is what is wanted, and this, as all experience shows, is what the Universities can do better than anyone else. And no exorbitant amount of time need be demanded for this purpose. If the student has learnt the elements of science at school, three years at most should suffice for the preliminary degree course. The graduate, armed with the necessary manipulative skill, would then start research work under proper guidance as the second and more valuable portion of his University training. And here the new research degree (by whatever name it may be called) may give us most valuable help. I hope that serious work will be demanded for it, and that the research course will become the recognised avenue to science fellowships and lectureships in the University. Two years would show what the man had in him. In that time either he would have proved himself no chemist, or he would have made some useful advance in our knowledge, and would have secured a testimonial of fitness such as no examination could confer. Five years in all—the minimum time now laid down for a medical qualification—would surely be not too much to ask for the chemist's training.

No extra expense need be incurred to carry out this plan. Some of the college scholarships at present offered on entrance might be reserved for research studentships on graduation. These studentships should be the reward of the successful undergraduate career. On this point, which I have urged for many years, I am glad to find myself in entire agreement with the President of the Chemical Society. At Owens College our most successful endowment in Chemistry has been the Dalton Scholarship, awarded for a research done in the College laboratories. In the Victoria University we have lately founded scholarships for the encouragement of research, which are awarded on the results of the final examination in the several Honours Schools. The winners are entitled to hold their scholarships at any university at home or abroad where they can continue their special studies.

I plead, then, for greater encouragement of chemical research in Oxford. Make it part of the normal course of training for everyone who wishes to be a chemist in fact as well as in name. Consider, not only the country's need, but the value of research itself as a mental training, as stimulating and strengthening the activities, as creating that sense of devotion and discipleship which becomes the tradition of every great school of learning.

Lastly, let us own that we ourselves—the teachers here—have been perhaps too critical, too much afraid of making mistakes, forgetting that the witty American's remark—that he who never makes mistakes never makes anything—has a far wider application in science than in politics. Only by practice and drill can we learn to collect our strength and swing it with precision into acts. Without that training, no matter how much faculty of seeing a man has, 'the step from knowing to doing' is rarely taken. There is nothing, I believe, in Oxford antagonistic to our cause. The genius of the place has not declared against scientific research; and if it be a true saying that men here imbibe a liberal education from the very air breathed by Locke and Berkeley, surely we also may draw scientific inspiration from this air, not only breathed, but first explained by Boyle and Hooke and Mayow.

The following Reports and Papers were read:—

1. *Report of the Committee on an International Standard for the Analysis of Iron and Steel.*—See Reports, p. 237.

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2. *Report of the Committee on Electrolytic Methods of Quantitative Analysis.*—See Reports, p. 160.

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3. *On the Proportions of Carbonic Acid in Air which are Extinctive to Flame, and which are Irrespirable. By* FRANK CLOWES, *D.Sc., Professor of Chemistry in the University College, Nottingham.*

It is generally maintained that a man cannot breathe air which contains sufficient carbon dioxide to extinguish a candle-flame. The correctness of this statement is of great importance to those who have occasion to work in an atmosphere which may contain large proportions of carbonic acid, such as that in a colliery or mine, or in a well-shaft.

The careful determination of the proportion of carbonic acid in air which is just sufficient to extinguish flame has been made by the author, the method adopted differing essentially from the methods previously employed. Experiments by earlier investigators had shown very wide discrepancies.

The author finds that the flames of candles, oil, paraffin, and alcohol are extinguished by air containing from 13 to 16 per cent. of carbonic acid. The flame of coal-gas, however, required the presence of at least 33 per cent. of the extinctive gas, and the flame of hydrogen was not extinguished until the amount of carbonic acid in the air reached 58 per cent.

Taking 15 per cent. of carbonic acid as the proportion in air which is extinctive of ordinary portable illuminating flames, it is of interest to note that this percentage of the gas in air appears from the recent experiments of Mr. J. R. Wilson[1] to be quite harmless when breathed. Mr. Wilson found that a rabbit which had breathed for an hour air containing 25 per cent. of carbonic acid was none the worse for its experience, but appeared at the end of the hour more lively than at the beginning. Air containing 50 per cent. of carbonic acid, however, proved fatal to the rabbit after it had been breathed for a few minutes only. Unfortunately no intermediate proportions were experimented with.

It is therefore apparently safe to say that air containing at least 10 per cent. of carbonic acid more than that required to extinguish a candle-flame can be breathed with impunity. Probably a much higher proportion of carbonic acid than this can be breathed.

Dr. Angus Smith and many others fully support from experience the statement that a man can breathe and work in air containing more than sufficient carbonic acid to extinguish a flame.

The extraordinary vitality of the hydrogen-flame in the presence of high proportions of carbonic acid renders it valuable for maintaining the flame in a miner's safety-lamp in foul air. The composite safety-lamp described by the author at the Nottingham Meeting of the British Association[2] serves this purpose well. It can burn either an oil-flame or a hydrogen-flame or both together. When used for gas-testing, one of the flames only is used as occasion may require. But it has been found that when the lamp runs the risk of being carried into foul air, it is most advantageous to burn the hydrogen-flame alongside the illuminating oil-flame. A comparatively low proportion of carbonic acid extinguishes the oil-flame, and this would leave the miner in darkness and without the means of recovering his light, since the lamp may not be opened and relighted in the mine. But the hydrogen-flame continues burning in the presence of over 50 per cent. of carbonic acid, and will rekindle the oil-wick after the foul air has been left or passed through.

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[1] *American Journ. Pharm.*, 50, No. 12.

[2] *British Assoc. Report*, 1893, p. 728.

It is worthy of note that the proportion of carbonic acid which was extinctive of any particular flame was independent of the size of the flame.

Further, it was noticed that the wick-fed flames gradually diminished in size as the proportion of carbonic acid in the air was increased; this was evidently due to the lowered temperature of the flame leading to a diminished supply of combustible gas or vapour being produced from the combustible solid or liquid; the flame ultimately died because it was starved of fuel. The flames of gases fed from jets, on the other hand, increased in size as the proportion of carbonic acid in the air was increased. It appeared that the flame extended its surface in the air containing a diminished proportion of oxygen, in its endeavour to obtain the supply of oxygen necessary for its combustion. This expansion of the flame lowered its temperature ultimately below the kindling point of the gas, and the flame was therefore extinguished by being cooled. The extinctive proportions of carbonic acid for different flames was therefore determined by the amount of oxygen required for combustion, and by the extent to which the temperature of the flame in air surpassed the kindling point of the combustible gas or vapour.

Results obtained with Naked Flames.

Combustible Substance burnt in the Mixture	Extinctive Proportion of Carbon Dioxide added to the Air		
	Percentage of Carbon Dioxide added	Percentage Composition of the Mixture	
		Oxygen	Nitrogen and Carbon Dioxide
I.—Candle	14	18·1	81·9
Colza and petroleum	16	17·6	82·4
Ordinary lamp paraffin	15	17·9	82·1
Alcohol, pure	14	18·1	81·9
Alcohol, methylated	13	18·3	81·7
II.—Hydrogen	58	8·8	91·2
Coal-gas	33	14·1	85·9
Methane (fire-damp)	10	18·9	81·1
Carbonic oxide (white-damp)	24	16·0	84·0
Ethylene	26	15·5	84·8

4. *On some Experiments with Free Hydroxylamine.*

By Dr. C. A. Lobry de Bruyn, *Amsterdam.*

The President of this section, Professor H. Dixon, has invited me to give some account of my researches concerning free hydroxylamine. In responding to this friendly request, I only propose to show you some of the properties of this substance by some experiments, for the time at my disposal forbids a detailed treatment of the subject; moreover a paper, containing the results of the investigation, has been published *in extenso,* in the 'Recueil des Travaux Chimiques des Pays-Bas.'

In a few words I may remind you that the free base can be prepared in the following way. The hydrochloric acid salt of the base is dissolved in absolute methyl alcohol, the equivalent quantity of methylate of sodium is added, the common salt which precipitates is filtered off, and the solution of the free base concentrated by distillation at 100 or 200 mm. By fractionating the residue at the pressure of 20 mm., the pure free base passes over at 58° as a crystallised substance melting at 33°; it is of a high specific gravity (1·35), without odour, hygroscopic and volatile.

The reason why the free hydroxylamine must be distilled at a low pressure is that the substance is pretty violently explosive, and that explosion occurs spontaneously at the temperature of 130°. Thus care must be taken never to heat the substance too strongly, for if heated at the ordinary pressure to 70° or 80°, an explosion may occur, the spontaneous decomposition raising the temperature. The hydroxylamine is an endothermous compound, and can be transformed totally into gaseous products, the two conditions which, as is known, characterise an explosive. I have produced an explosion in the following manner: 1 or 1·5 c.c. of the melted base were put into an ordinary open test-tube, with a thermometer in it; the tube stood in an ordinary beaker, which, heated by a burner, acted as an air-bath. When the temperature had reached 90°, the flame was withdrawn; the spontaneous decomposition was vigorous and the temperature rose to 130.° Then a violent explosion took place, the glass apparatus was reduced to powder, the copper-gauze on which the vessel stood was torn to pieces, phenomena which prove that the explosion is of the same nature as that of high explosives. If one drop of the melted base in a tube is brought into a flame, a loud explosion is heard.

The free base can burn in the air with a feeble yellowish flame.

That hydroxylamine is a highly reducing agent is known since Lossen, about thirty years ago, discovered the salts of the base. It is obvious that the free base must show reducing properties in a much higher degree. On exposure to the air at the ordinary temperature it gradually attracts oxygen; one of the products of the oxidation is nitrous acid. When the free surface in contact with the air is extensive the oxidation is accompanied by a rise of temperature—for instance, when some filter paper or asbestos is moistened with the melted substance. A current of oxygen passing over the substance gives rise to the formation of fumes containing nitrous acid, the temperature rising at the same time.

It is not surprising that oxidising agents act violently with the free base; thus, for instance, the solid permanganate of potassium, chromic acid, and some peroxides, in contact with some drops of the substance, produce inflammation. Powdered bichromate of potassium causes a sharp detonation; solid iodate of sodium and nitrate of silver are also reduced instantaneously. The action of anhydrous sulphate of copper is also very violent; the reduction of the salt may be accompanied by inflammation.

Metallic sodium also acts violently, producing a flame. If the action is moderated by adding some dry ether, hydrogen is evolved and a white substance, $NaONH_2$, is formed. This compound is a dangerous one because it explodes by contact with the air.

The halogen acts vehemently with the free base; chlorine inflames it; bromine and iodine disappear immediately, producing the corresponding acids, water, and nitrous oxide.

As to the solvent properties of the free base, these are nearly equal to those of water. It dissolves different salts, some of them, as for instance KI, in great quantity. Gaseous ammonia, introduced at 16° into the melted base, is dissolved rapidly and gives a solution containing 20 per cent. of the gas.

In the same way the substance behaves like water with respect to other liquids; it is consequently only easily soluble in the alcohols and nearly insoluble in the ordinary organic liquids. Methyl and ethyl alcohol are miscible with the melted base in every proportion; these solutions, however, below the melting point of the base are supersaturated with respect to the solid compound. There exists, however, a difference between liquid hydroxylamine and water, the former not being miscible in all proportions with propyl alcohol.

That hydroxylamine can occupy the place of the hydrate water in salts has been proved by Crismer, who has prepared the salts $ZnCl_2, 2NH_2OH, BaCl_2, NH_2OH$, &c.; by means of dry ammonia Crismer has prepared the free base from these double-compounds.

The presence of the hydroxyl group in hydroxylamine explains the analogies between this substance and water; the difference in their behaviour must be explained, at least partly, by the greater molecular weight of the former.

Solid caustic soda is also very soluble in the melted base; care must be taken to keep it cool when adding the soda. This solution is much more liable to oxidation than the free base; exposed to the air the solution may spontaneously inflame. So we see that the presence of alkali (or rather of $NaONH_2$) increases in a high degree the liability to oxidation, the free base oxidising not so quickly as the solution of NaOH in it, while the solid $NaONH_2$ explodes in contact with the air.

Although, as has been shown, free hydroxylamine is a strong reducing agent, it can be reduced itself by means of zinc dust. If this substance is moistened with the base (in an atmosphere of nitrogen), a pretty violent reaction occurs five or ten minutes later, and ammonia and zinc oxide are formed.

5. *The Chemical Action of a New Bacterium in Milk.*

By ALEXANDER BERNSTEIN.

Up to the present time the chemical action of bacteria on sugar has received the largest share of attention, the alcoholic and acid fermentations offering themselves most readily for observation.

In regard to the effect of bacteria on casein, it has generally been considered as sufficient to say that some bacteria seem to have a rennet-like action, whilst others have a peptonising effect. It was assumed that a certain class of bacteria have the peculiarity of producing an enzyme which curdles the milk under alkaline reaction, and afterwards producing another enzyme which dissolves the curd again. Such actions can be noticed if a milk is strongly heated and then left to itself.

The author succeeded in isolating a bacterium, which had such an unusual effect on sterilised milk, that further studies appeared desirable. These investigations have been carried on by the author at the Hygienic Institute of Berlin.

The special bacterium is a very short rod, scarcely 1μ[1] long and $\cdot 5\mu$ in diameter: it shows rapid whirling motion, forms colourless liquid colonies on peptone-gelatine, which is soon entirely liquefied; on agar a white slimy growth; on potatoes a smooth brown skin. No spores could be observed. The microbe has received the name *Bacterium peptofaciens.*

A practical method of inoculating large quantities of milk with this bacterium was next described, the object being to obtain a new product out of milk in which all the casein is in a dissolved state, as it is well known that ordinary milk is not easily digested by many grown-up persons on account of the undissolved state of the casein.

Milk which had been deprived of its cream by separators was used for this purpose. After incubation during eight days at 20° C. the further action of the bacterium was prevented by heating the milk. This killed the bacteria and caused coagulation of that part of the casein which had not been dissolved. A clear filtrate was obtained: it had a yellow-reddish colour, an aromatic smell, and a taste reminding one of almonds.

The results of a detailed chemical analysis were given. It was shown that more than one-half of the casein had been hydrated and formed into albumose and peptone. The various reactions of the dissolved protein substances were stated.

A small amount of lactic acid was formed, and a very slight amount of acetic and butyric acids, these last two together coming only to ·03 per cent. The bacterium does not produce any gaseous products, even after weeks of action. Sulphuretted hydrogen, indol, and skatol were not formed. The sulphur of the casein was still contained in the peptone. Ammonia was present in the form of salts, the amount of ammonia being equal to ·07 per cent. Of tyrosin only the existence could be shown, the amount being too small to show crystals under the microscope.

Reference was made to similar products generated during the ripening of cheese, which is entirely the action of microbes.

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[1] $1\mu = 0\cdot001$ mm.

The liquefied milk is slightly concentrated by evaporation, and to the new product so obtained the name of 'galacton' has been given. The investigation in regard to any enzyme being formed by the *Bacterium peptofaciens* gave the result that this is not the case. As compared to the meat peptones now largely used, the galacton has the advantage of containing no gluten-peptone, which probably explains the much better taste; further, that no chemicals, such as hydrochloric acid, are required in its preparation.

Formerly it has been supposed that milk-sugar could only undergo acid fermentation, but lately special yeasts have been found which produce alcoholic fermentation of milk-sugar. By means of such yeasts an alcoholic beverage can be made out of galacton.

The author concluded with the remark that bacteria have of late been most conspicuous in the minds of most people by the fact that, out of the enormous number of bacteria existing, there are a few which have pathogenic effect. But the action of bacteria in nature is an eminently useful one, and by the chemical study in this direction we shall learn how to utilise their peculiar action to our advantage.

FRIDAY, AUGUST 10.

A discussion on the behaviour of gases with regard to their electrification and the influence of moisture on their combination was opened by the reading of the three following papers:—

1. *On the Connection between Chemical Combination and the Discharge of Electricity through Gases. By* Professor J. J. Thomson, *M.A.*, *F.R.S.*

[This paper was ordered to be printed *in extenso.*—See Reports, p. 482.]

2. *On the Electrification of Molecules and Chemical Change.*
By H. Brereton Baker.

[This paper was ordered to be printed *in extenso.*—See Reports, p. 493.]

3. *On the Rate of Oxidation of Phosphorus, Sulphur, and Aldehyde.*
By Thomas Ewan, *B.Sc.*, *Ph.D.*

Gaseous oxygen appears sometimes to be more active chemically in the dilute state than when it is more concentrated. This remarkable behaviour was studied in the cases of phosphorus, sulphur, and aldehyde, by the author in Professor van't Hoff's laboratory in Amsterdam.

With phosphorus and oxygen (saturated with aqueous vapour at about 20°) it was observed that for pressures of oxygen greater than 700 mm. the rate of oxidation was excessively small or nothing at all. Below 700 mm. it increases rapidly. This limit corresponds with that found by Joubert, below which phosphorescence begins. After reaching its maximum velocity a very simple relation exists between the rate of oxidation and the pressure of the oxygen, provided that the change in the rate of evaporation of the phosphorus, which, according to Stefan, is produced by the change in the pressure of the oxygen, is taken into account. The rate of oxidation is then directly proportional to the pressure of the oxygen. In the absence of water the oxidation also begins suddenly, but at a much lower pressure (about 200 mm.). Again allowing for the change in the rate of evaporation of the phosphorus, the velocity of the reaction quickly reaches a maximum and then decreases, as nearly as could be made out, proportionally to the square root of the pressure of oxygen. The results here were not so certain as might be desired, owing to the layer of oxide formed on the surface of the phosphorus disturbing the regular course of the reaction.

With sulphur in dry oxygen, where the course of the reaction can be conveniently followed at 160°, it appears (again allowing for the change in the rate of evaporation) that the velocity of the reaction is proportional to the square root of the oxygen pressure.

No limit was observed here up to 800 mm., beyond which no observations were made.

To eliminate the uncertainty introduced by the correction for the rate of evaporation of the phosphorus and sulphur, the reaction between the vapour of acetaldehyde and oxygen was studied (at 20°). The reaction was found to go perfectly regularly, and its velocity was proportional to the product of the pressure of the aldehyde vapour and of the square root of the pressure of the oxygen gas.

The interpretation of these facts would appear to be that only that small part of the oxygen which is broken up into atoms takes part in the oxidation.

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4. *New Methods of Spectrum Analysis, and on Bessemer Flame Spectra.*
By Professor W. N. Hartley, *F.R.S.*

This communication comprises three parts:—

1. *On the Separation of Spectra of the Alkalies from those of the Alkaline Earths.*—This is accomplished by fusing the material with boracic acid, hydrated silica, or dissolving in hydrofluosilicic acid. The salts so formed are used in the ordinary manner in a Bunsen flame.

2. *Methods of obtaining Spectra with Flames at High Temperatures.*—The difficulty of obtaining spectra at high temperatures arises from the necessity of having a support for the substances to be examined which is practically infusible in the oxy-hydrogen flame. The mineral kyanite from County Donegal is suitable for supports in the oxy-hydrogen blow-pipe flame. A commoner material is ordinary tobacco-pipe, which serves as a support for various metallic salts. The spectra obtained in the oxy-hydrogen flame have the following characters, by which they may be classified:—

(1) Lines: lithium, thallium, nickel, cobalt.
(2) Bands: antimony, bismuth, gold, tin, sulphur, selenium.
(3) Bands and lines together: copper, iron, manganese, tellurium, lead, and silver.
(4) More or less continuous spectra with lines: sodium, potassium, magnesium, chromium, cadmium.
(5) Continuous spectra: zinc, carbon, arsenic.
(6) No spectrum: platinum.

Band spectra can be converted into line spectra by reducing the quantity of substance in the flame. This is shown by the lines of silver which are found to be present in spectra obtained from ordinary copper; the spectrum of silver being itself a band spectrum. A distinct flame spectrum may be emitted by compounds at high temperatures. Examples of such spectra are those of magnesia, lime, copper-oxide. Some compounds emit only the spectra of the metals they contain; such are compounds of iron, nickel, cobalt, chromium, manganese, sodium, potassium, lithium, thallium, and rubidium.

3. *Bessemer Flame Spectra.*—Up to the present time the precise nature of the spectrum, the cause of its production, its sudden disappearance when decarburisation of the metal takes place, and the connection between the decarburisation of the metal and the extinction of the spectrum, have not been satisfactorily explained. According to Roscoe, Lielegg, Kupelwieser, and Spear Parker, the spectrum is characterised by bands of carbon or of carbon monoxide, which disappear when all carbon is burnt out of the metal.

On the other hand, according to the investigations of Simmler, Brunner, von Lichtenfels, and Wedding, the spectrum is not due to carbon (Roscoe), or to carbon monoxide (Lielegg and Kupelwieser), but to manganese and other elements in the pig-iron.

The very careful examination of these spectra by Watts, and his comparison of them with that of the Bessemer flame, led to the conclusion that it was not the spectrum of carbon in any form, or of manganese, but that of manganic oxide.

The spectrum is a complex one, which exhibits differences in constitution during different periods of the 'blow,' and even during different intervals in the same period. As originally observed by Watts, the spectrum differs in different works, the difference being due to temperature and to the composition of the metal blown.

During the First Period.—The lines of the alkali metals, sodium, potassium, and lithium, are seen unreversed on a bright, continuous spectrum caused by carbon monoxide. The C line of hydrogen, and apparently the F line, were seen reversed during a snowstorm, when much moisture entered the metal with the blast.

During the Second Period, the 'Boil.'—Bands of manganese are prominent, overlying the continuous spectrum of carbon monoxide. There are lines of carbon monoxide, manganese, and iron, also those of the alkaline metals.

During the Third Period, the 'Fining Stage.'—The spectrum is the same as the foregoing, but the lines of iron are not so strong and not quite so well defined. Some of the short lines of iron disappear; the lines of the alkali metals are visible.

The alkali metals do not show themselves in the Bessemer flame until a layer of slag has been formed and the temperature has risen sufficiently high for these basic constituents to be vaporised. At the temperature of the 'boil,' or second period, both metallic manganese and iron are freely vaporised in a current of carbon monoxide which rushes out of the bath of molten metal. The evidence of this is the large number of bands of manganese and lines of iron in the spectrum.

When the metal blown contains but little manganese, the manganese spectrum in the flame does not arise from that substance being contained in the bath of metal; it must be vaporised from the slag. That this is so has been proved by photographs of the spectrum from samples of slag obtained from the Crewe works. This explains the fact observed by Brunner, namely, that when a converter is being heated with coke after it has been used, but not relined, the spectrum of the Bessemer flame makes its appearance; manifestly it comes from the adhering slag.

The luminosity of the flame during the 'boil' is due, not merely to the combustion of highly heated carbonic oxide, but also to the presence of the vapours of iron and manganese in the gas.

The disappearance of the manganese spectrum at the end of the 'fining stage,' or third period, is primarily due to a reduction in the quantity of the heated carbon monoxide escaping from the converter, which arises from the diminished quantity of carbon in the metal. When the last traces of carbon are gone, so that air may escape through the metal, the blast instantly oxidises any manganese either in the metal or in the atmosphere of the converter, and furthermore oxidises some of the iron. The temperature must then fall with great rapidity.

The entire spectroscopic phenomena of the 'blow' are undoubtedly determined by the chemical composition of the molten iron, and of the gases and metallic vapours within the converter, the temperature of the metal, and that of the issuing gases.

The Temperature of the Bessemer Flame.—The probable temperature of the Bessemer flame at the finish is that produced by the combustion in cold air of carbonic oxide heated to about 1,580° C.—that is to say, to the temperature which, according to Le Chatelier,[1] is that of the bath of molten metal from which the gas has proceeded.

5. *On the Chemistry of Coal Formation.*
By J. W. Thomas, *F.I.C., F.C.S.*

The age of the coal, and the physical conditions, such as the effect of water, heat, and pressure, should throw light upon the chemistry of coal formation; but the coals in one 'field' are found under different physical and chemical conditions from those of another, and little evidence is obtained by comparison.

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[1] *Comptes Rendus*, vol. cxiv.

The decomposition of peat and of wood teaches us more of the chemistry of coal formation. In both instances the woody fibre disappears first, leaving a residue richer in resinoids. The lignites of Bovey Tracey have, as in the case of decaying peat and wood, an excess of resinoid matters over the vegetation which formed them. Hutton found mineral resin in Carboniferous coals, and others since. Witham showed long ago, and much recent evidence proves, that conifers and other dicotyledons flourished during the Carboniferous period. Just as lime and other trees shed saccharine matter on the leaves and grass underneath, so it is probable that liquid, gummy, and resinous matters were showered from the forest vegetation during the Carboniferous and Tertiary periods.

The chemical changes in coal formation took place chiefly at and near the surface. In the formation of paraffin shale and some Scotch cannels the woody fibre of the forest growths was destroyed, little else but bituminous matters remaining. A resinous vegetation without much dicotyledonous trees, or if with dicotyledons, considerable surface exposure and decomposition of the woody fibre, would produce rich bituminous coal, Wigan cannel, &c. A luxuriant resinous and dicotyledonous vegetation, assisted by heat and pressure, without much surface decomposition, probably gave rise to semi-bituminous, steam, and anthracite coal.

Our present chemical knowledge of coal may be summed up as follows:—

1. It contains water after air-drying. The hygroscopicity of coal has not received due attention. The water is in chemical combination. Further, the hygroscopicity is most probably the key to the spontaneous combustion of coal.

2. Coal contains the gases, liquids, and solids of the paraffin series, but these together will not make up more than 1 per cent. of Carboniferous coals.

3. The bulk of coal is carbon, with more or less hydrogen, oxygen, nitrogen, sulphur, and ash. We shall probably never know how the carbon is combined or how much is in the free state.

Further experiments are suggested as follows:—

1. Upon the decomposition of dicotyledons to throw light upon the formation of coal.

2. Upon the hygroscopicity of coal; and to study its bearings upon the spontaneous combustion of coal on board ship.

3. Upon coals from all British coal-fields, to determine the quantity and, if possible, the constituents soluble in gasolene (petroleum ether) or benzine as employed by Mr. Watson Smith.

4. To act upon the various coals with a weak solution of potassic hydrate.

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6. *On the Iodine Value of Sunlight in the High Alps.* *By* Dr. S. Rideal.

At the meeting of the Association in Nottingham I had an opportunity of submitting the values of the sunlight in the Upper Engadine in terms of the amount of iodine liberated from an acidulated solution of potassium iodide during the month of January 1893. These experiments have been continued during the months of January and February of the present year by my brother, A. W. Rideal, and the results may therefore not be without interest. The recent experiments were conducted in exactly the same way as those of last year, so that in all respects they are strictly comparable.

The solutions were standardised by standard iodine solution prepared in England, and the hyposulphite solution was checked against this solution from time to time during the progress of the experiments.

During the last winter the weather was, on the whole, bad, and the number of days on which snow fell or which were overcast were more numerous than in the corresponding period of last year.

The maximum value was obtained on February 4, and was equal to 14·52 mgms. of iodine per 100 c.c., as compared with 13·5, the maximum value on January 1, 1893. The lowest value was 3·53 on December 9, 1893, as against 5·7 on

January 24 of last season. The number of bad days on which little or no sun was recorded lowers the average for the period under examination. It amounts to 7·05 mgms. per hour, whilst in January 1893, taking only the bright days, the quantity was 9·34.

I understand that the ordinary meteorological record was kept as usual, and that the data are to be found in the 'Alpine Post' for the days on which these experiments were carried out. I append, however, a brief note as to the atmospheric conditions in a separate column.

Date	No. of Hours	Total Mgms. Iodine per 100 c.c.	Hour Value	Conditions
1893. Dec. 6	3·5	27·93	7·98	Sunny
,, ,, 7	4·5	35·5	7·88	,,
,, ,, 8	5·5	36·08	6·56	,,
,, ,, 9	4·75	26·77	3·53	Overcast
,, ,, 10	5	35·5	7·1	Sunny
,, ,, 11	4·25	33·75	7·94	Sun with clouds
,, ,, 29	5	37·83	7·56	Sunny
,, ,, 30	5	32·01	6·4	Sun, but solution frozen
,, ,, 31	7	38·99	5·57	Sunny, solution frozen
1894. Jan. 1	4·5	34·33	7·63	Sunny
,, ,, 2	4·5	26·77	5·95	,, some clouds
,, ,, 3	5	21·53	4·3	,, overcast 2 hours
,, ,, 4	4·5	19·73	4·39	Overcast
,, ,, 5	4·5	20·95	4·65	Very little sun
,, ,, 6	4·5	16·85	3·74	No sun, snowing
,, ,, 7	5·5	20·95	3·89	,, ,,
,, ,, 8	5·25	19·78	3·77	Overcast most of the day
,, ,, 9	4·5	35·5	7·88	Sunny
,, ,, 10	5	37·53	7·5	,,
,, ,, 11	5	42·48	8·45	,,
,, ,, 12	5	39·86	7·97	,,
,, ,, 13	5	54·12	10·82	,,
,, ,, 14	5	34·63	6·92	,,
,, ,, 15	5·75	38·99	6·78	,, ¾ hour after sunset
,, ,, 16	5·25	41·61	7·92	,,
,, ,, 17	5	34·92	6·98	,,
,, ,, 18	5	22·98	4·59	Cloudy
,, ,, 19	5	22·11	4·42	Snowing
,, ,, 20	5	35·79	7·15	Sun and clouds
,, ,, 21	5·25	44·23	8·42	Sunny
,, ,, 22	5·25	42·77	8·14	,,
,, ,, 23	5	18·62	3·72	Snow all day
,, ,, 24	5	21·82	4·36	Snowing
,, ,, 25	5·25	43·65	8·31	Sunny
,, ,, 26	4·75	24·15	5·08	Snowing
,, ,, 27	5·5	48·88	8·88	Sun with clouds
,, ,, 28	5·5	73·04	13·28	Sunny
,, ,, 29	5·75	46·56	8·09	Overcast
,, ,, 30	5·75	58·49	10·17	Fair, not much sun
,, ,, 31	5·5	22·89	4·16	Half sun and overcast
,, Feb. 1	5·75	21·86	3·80	Overcast, snow
,, ,, 2	5·75	34·38	5·98	,, ,,
,, ,, 3	6·5	44·91	6·91	Not much sun
,, ,, 4	6	87·17	14·52	Sun all day
,, ,, 5	6·5	64·41	9·90	Sunny
,, ,, 6	7	38·71	5·53	Sun and clouds
,, ,, 7	6·5	72·69	11·18	Sunny
,, ,, 8	7	39·89	5·69	Sun and clouds
,, ,, 9	7	56·73	8·10	,, ,, ,,

Date	No. of Hours	Total Mgms. Iodine per 100 c.c.	Hour Value	Conditions
1894. Feb. 10 .	8	58·21	7·27	Sun and clouds
„ „ 11 .	7	50·83	7·26	„ „ „
„ „ 12 .	7	67·03	9·57	Sunny
„ „ 13 .	6·25	28·95	4·63	Sun 1½ hour, then snow
„ „ 14 .	7	46·98	6·71	„ then overcast
„ „ 15 .	8	52·00	6·50	„ „ „
„ „ 16 .	5·5	38·11	6·92	„ „ „
„ „ 17 .	6·5	26·59	4·09	Snow, little sun
„ „ 18 .	7	55·25	7·89	Sunny
„ „ 19 .	6·5	36·64	5·63	Sun and clouds
„ „ 20 .	7	55·84	7·97	Sunny
„ „ 21 .	6·5	54·96	8·45	„
„ „ 22 .	7·3	65·25	8·70	„ but 1½ hour after sundown
„ „ 23 .	7	59·16	8·45	Sun and overcast
„ „ 24 .	6·75	36·83	5·45	Overcast
„ „ 25 .	6·75	55·10	8·10	Sun and clouds
„ „ 26 .	7	32·77	4·48	Snow and rain
„ „ 27 .	6·75	60·90	9·02	Sunny
„ „ 28 .	7·25	82·87	11·43	Sun 1 hour after sundown

It has been remarked in the Engadine that the amount of sunlight during the winter months has been diminishing, but so far as I have been able to ascertain, there is no accurate information upon which a statement of this character can be based. The average value per hour obtained from my experiments last year for the month of January, including the bad days, amounted to 8·41 mgms. of iodine per 100 c.c., per hour, whilst, as already mentioned, the mean from the above experiments, extending over a longer period, is 7·05. This shows that the average amount of light was less during the 1893–4 season than during the previous one, but I do not think that from the records of two seasons any deductions can legitimately be made.

I hope to make arrangements for a continuance of this work during the ensuing winter, and should be glad to hear of similar work being carried on at some of the other centres in the High Alps.

7. *Interim Report of the Committee on the Formation of Haloids from Pure Materials.*

8. *Interim Report on the Bibliography of Solution.*—See Reports, p. 246.

SATURDAY, AUGUST 11.

The Section did not meet.

MONDAY, AUGUST 13.

1. *A joint meeting with Section A was held, at which* Lord **Rayleigh**, *Sec.R.S., and* Professor W. **Ramsay**, *F.R.S., gave a preliminary account of a New Gaseous Constituent of Air.*

The following Papers were read:—

2. *On Schuller's Yellow Modification of Arsenic.*[1]
By Professor H. McLeod, *F.R.S.*

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3. *On the Electrolysis of Glass.*
By Professor W. C. Roberts-Austen, *F.R.S.*

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4. *On the Relations between the Viscosity of Liquids and their Chemical Nature.*[2] *By* Dr. T. E. Thorpe, *F.R.S., and* J. W. Rodger.

During the past four years the authors have been making observations on the viscosity of liquids with the view of establishing relationships between this property on the one hand and molecular weight and molecular structure on the other. They have employed the tube-method of measuring the viscosity coefficient, and in the case of each liquid the observations extend over the temperature range between 0° and the ordinary boiling-point. More than eighty liquids have now been examined.

For liquids which do not appear to contain molecular aggregates, at any temperature, the following conclusions may be drawn:—

1. In homologous series the viscosity coefficient is greater the greater the molecular weight.
2. The coefficient of a normal compound is greater than that of the isomeric iso-compound.
3. The coefficient of an allyl compound is intermediate to those of the corresponding normal propyl and iso-propyl compounds, and, in general, constitution exerts a regular effect on the viscosity coefficient.

Liquids which appear to contain complex molecules in certain cases do not obey these rules. Formic and acetic acids are exceptions to Rule 1. The alcohols do not conform to Rules 2 and 3. In general, the effect of temperature upon viscosity is much greater for complex than for simple liquids. In both classes of liquids the behaviour of the initial members of several homologous series does not accord with that of higher homologues.

In attempting to quantitatively connect viscosity with chemical nature, the authors have used two magnitudes—the *molecular viscosity* and the *molecular viscosity-work*—which may be derived from the viscosity coefficient. If η be the viscosity coefficient and v be the molecular volume, the molecular viscosity is $\eta v^{\frac{2}{3}}$, or the product of η and the molecular area. The molecular viscosity-work is ηv, the product of η and the molecular volume. The values of these magnitudes have been examined at three different series of temperatures of comparison—viz., the ordinary boiling-points, the corresponding temperatures of 0°·6, and temperatures of equal slope or points on the viscosity curves at which temperature is exercising the same effect upon the viscosity of each liquid. On ascribing definite partial values to the atoms and the different modes of atom-linkage—the iso-grouping, double linkage, the ring-grouping, &c.—it has been found possible to calculate the viscosity magnitudes of the great majority of the simple liquids. The results obtained at equal slope are by far the most precise, but even here the alcohols, water, and, to a less extent, the acids are anomalous, doubtless on account of the influence of molecular complexity. A strong point in favour of the new method of using equal slope as a condition of comparison is that the stoichiometric relationships obtained at any one value of the slope appear to be general, and thus to be independent of the particular value of the slope at which the comparisons are made. This conclusion applies even to complex liquids like water and the acids, but not to the alcohols, which of all the liquids examined exhibit, at all of the systems of comparison, the most exceptional behaviour.

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[1] Published in the *Chemical News*, lxx., p. 139, Sept. 21, 1894.

[2] Published in full in the *Phil. Trans.*, 1894.

5. *Some Experiments on the Rate of Progress of Chemical Change.*

By DR. J. H. GLADSTONE, *F.R.S.*

In the last February number of the 'Philosophical Magazine' Mr. Veley pointed out four stages of a chemical reaction: 'First, the commencement; second, the period of inertness or reluctance, followed by acceleration; third, of constancy; fourth, of diminution of velocity.' This reminded the author of various old experiments which had never been published, and he returned to the subject with a view of seeing whether this period of inertness followed by acceleration occurred in such simple cases as that of reciprocal decomposition of salts, and whether, where it did occur, it was capable of any explanation on known principles. The reciprocal decomposition of potassio-platinum-chloride and potassium-iodide slowly produces the iodine salt which makes itself manifest by its deep red colour. In examining this in various ways the action always appeared most rapid at first and gradually slackened till a balance of the salts in solution was obtained. In such cases, on the contrary, as that of the formation of bitartrate of potassium or calcium, where a larger amount of the products is formed than can be kept in solution, it is some time before crystals make their appearance, and then they come with a rush, gradually diminishing to the end of the reaction. This seems to be due partly to the phenomenon of super-saturation and partly to the necessity of rapid redistribution of the acids and bases when the bitartrate produced is thrown out of the field of action and reaction. In cases where almost insoluble salts are formed, such as strontium sulphate, the liquid becomes milky almost at once, a constant redistribution being necessitated by the separation of the insoluble salt, and the curves representing the course of the action closely resembled those of the platinum salt given above.

There are unquestionably many cases in which there is very little appearance of action at first, but afterwards it comes on rapidly, and then, of course, diminishes. The formation of zinc-methyl was quoted, but a more interesting instance was the reaction between cuprous oxide and silver nitrate in rather weak solution. At first little or nothing is seen; after a while long filaments of metallic silver shoot forth, the reaction becoming very rapid, until the silver solution is very much weakened, when, of course, it proceeds more slowly. In explanation of this we may conceive of some possible 'induction,' or charging up of the metallic oxide, or the influence of the local rise of temperature, or the greater scope for voltaic action between the growing silver and the copper compound. The author, however, did not insist on any particular explanation, but gave the facts as a contribution to the general subject.

6. *The Determining of the Freezing-point of Water, van't Hoff's Constant, Arrhenius' Law of Dissociation, Ostwald's Law of Dilution. By* DR. MEJER WILDERMANN.

I have already given an account, in the Physical Section, of the method devised, in concert with the late P. B. Lewis, for accurately determining the freezing-point of aqueous solutions which freeze at temperatures just below 0° C.

The depression of the freezing-point of a solution of any concentration is stated in degrees below the freezing-point of water. The freezing-point of water and of extremely dilute solutions is very difficult to determine with accuracy. Under ordinary circumstances a cap of ice forms round the bulb of the thermometer; if the formation of this cap is prevented, the freezing-point of water determined by my thermometer divided to 0°·001 is higher by 0°·0015 to 0°·0017 than when the cap exists and a constant error in the determination of the freezing-point is not removed.

The method of determining the freezing-point of very dilute solutions which was devised by my late friend P. B. Lewis, and my investigations of the freezing-point of water, and of extremely dilute solutions, give us a means of submitting van't Hoff's constant, Arrhenius' law of dissociation, and Ostwald's law of dilution to a more accurate verification.

It is well known that it was van't Hoff who first drew attention to the fact that the equations representing the generalisations arrived at by Boyle, Gay Lussac, and Avogadro in the case of gases are equally applicable to dissolved substances if the osmotic pressure of the dissolved molecules be substituted for the pressure of the gas.

While van't Hoff was able to establish a thermodynamic relation between the osmotic pressure of a dissolved substance and the molecular lowering of vapour pressure, the molecular lowering of the freezing-point of solutions furnishes a rational basis for the empirical generalisations of Raoult, and of Babo and Wüllner.

In van't Hoff's thermodynamical argument the solutions are assumed to be very dilute, and hence experimental verification is specially important for the case of such solutions.

I have found that in the case of aqueous solutions of sugar and urea the agreement between the value calculated by van't Hoff by means of the equation $t = \frac{0{\cdot}02\,T^2}{W}$ (which must equal 1·89 if $W = 79$ kal., and is 1·87 if $W = 80$ kal.) and the observed value of the constant is excellent. Even in the case of alcohol the values do not vary by more than $1\frac{1}{2}$ per cent. from 1·87—a difference which may be accounted for by the difficulty of determining exactly the percentage of alcohol in a solution from its density. That this is the case is shown by the fact that the value 1·84 or 1·85 is observed for all concentrations. It is also possible to calculate van't Hoff's constant without determining the freezing-point of water in the following way: Sugar, urea, and alcohol are not electrolytes, *i.e.*, are in water only very slightly dissociated. We can, therefore, determine the relation between concentration and depression of freezing-point, starting from a solution of any convenient concentration, where an ice cap is not formed, instead of from pure water, and thus eliminate the influence of any error in the determination of the freezing-point of water. From these observations made with my thermometers divided to 0°·01 and 0°·001 I have been able to establish van't Hoff's constant by a second independent method. Also, if the results obtained by Loomis with a thermometer reading to 0°·01 are similarly treated, the van't Hoff's constant becomes evident in the case of sugar, less evident in the case of water and alcohol, though the variations are so great that the probable error is greater than he suspected, and the concentration of the solution was probably wrongly determined.

We proceed to the generalisation of Arrhenius. Van't Hoff showed by four different methods that a law analogous to that of Avogadro was valid for solution of non-electrolytes like cane-sugar. It then became of importance to account for exceptional cases in which the depression of the freezing-point was abnormal, and in particular the cases of salts, acids, and bases in aqueous solutions. The explanation was given when Arrhenius showed that by two independent, quite different methods, the observation of the lowering of the freezing-point and of the electrical conductivity of a solution, the same value could be obtained for the factor i, which denotes the ratio of the pressure actually exerted by the substance to the pressure which the substance would exert if it consisted entirely of undissociated molecules. This law, which is of special importance owing to the light thrown by the dissociation-theory on various physical and chemical problems, must, like those of van't Hoff already mentioned, be more valid in very dilute solutions, and should at first be verified for them. For sugar, urea, alcohol, which are bad conductors of electricity, we have found normal depression and a constant 1·89 or 1·87. For KCl, SO_4H_2, dichloracetic acid, trichloracetic acid, and nitrobenzoic acid, which are good conductors and show at the same time abnormal depression, I found that the degrees of the dissociation from the lowering of freezing-point and from the electrical conductivity are nearly the same.

It is obviously desirable that Ostwald's dilution law, one of the laws of the action of masses, and a most important foundation for the theory of dissociation, should be verified by determinations of freezing-points, just as it has been verified by determinations of electrical conductivity; and for the reasons already stated the experimental verification is most important in the case of the most dilute solutions. The effect of experimental error in the calculation is here very considerable, and the freezing point methods hitherto in use have not been sufficiently delicate to verify the dilution law. The more accurate method already referred to has to a large extent supplied the deficiency, and in the case of trichloracetic acid and orthonitrobenzoic acid I have experimentally verified the validity of the dilution law $\frac{a^2}{(1-a)v}=k$. An account of these investigations will be given in the 'Journal of the Chemical Society' and in the 'Zeitsch. f. physik. Chemie.'

7. *On the Effect of Dilution upon the Colours of Salt Solutions and the Measurement of this Effect. By* WYATT W. RANDALL, *Ph.D.*

The writer called attention to the conclusions deduced by Ostwald from the hypothesis of electrolytic dissociation with regard to the source of the colour of salt solutions, and to the work of Knoblauch, Krüss, Traube, Arrhenius, Magnanini, Ostwald, Wagner, and others upon this subject. The experiments and conclusions of Vernon were then more particularly discussed, to show the inaccuracy which the author believes characterised them. A drawing was then shown of an apparatus, through the use of which the author hopes to be able to determine with comparative accuracy the effect of dilution upon the colours of salt solution. Since, according to the theory of electrolytic dissociation, the colour of a salt solution is due to the presence in it of free coloured ions, it follows that with increased dissociation the colour must become proportionally more intense. One of the simplest ways to produce more complete dissociation is by dilution. Hence a dilute solution, *ceteris paribus*, should, in proportion to the amount of salt contained, show a more intense colour than a concentrated one. In the apparatus shown the author examines the relative length of column of coloured solutions of different concentrations which show the same intensity of colour, in order to determine whether or not the colour remains proportional to the concentration. Several advantages claimed for the apparatus were pointed out. It is, for example, so arranged that the light transmitted through the stronger solution also passes through a column of water equal in length to the difference between the lengths of column of the concentrated and the dilute solutions. By this means any error due to the colour, &c., of the water of the solutions is presumably eliminated. The tubes through which the light is transmitted are silver-plated, and the measurements are made in a dark room, in order that all error due to diffused light may be removed.

The results, so far as they have gone, indicate that the colour remains practically proportional to the concentration, whereas in the solutions examined the dissociation varied in amount from about 25 per cent. to nearly 60 per cent. The author, however, desires his results thus far to be considered as merely preliminary. The behaviour of one solution examined suggests that the effect produced upon the colour by varying the rate of dilution, which Vernon claims to have noticed in the case of certain compounds of chromium, may be much more general than that investigator imagined. This point will in the future receive special attention.

8. *On the Distinction between Mixtures and Compounds.*
By P. J. HARTOG, *B.Sc.*

The distinction between mixtures and compounds, as it is now understood, dates from the controversy between Berthollet and Proust at the beginning of the century. Most text-books state that Proust showed that 'the same compound always contains the same elements united in the same proportions,' and imply that the statement does not hold good for 'the same mixture.' Interpreted literally, the statement is a mere truism, and applies equally to both classes of substances. By altering its form somewhat we are led to the postulate: 'Substances in other respects alike possess the same quantitative composition'—a postulate daily made use of in the laboratory, though it is not to be found in the text-books. This postulate was tacitly accepted by Berthollet as well as Proust, and has nothing to do with the distinction sought for; we see, therefore, that the points at issue between the two men have been misrepresented. The author has shown elsewhere[1] how this misrepresentation has arisen. Proust was unable to furnish the experimental distinction between compounds and mixtures which Berthollet demanded again and again; nor until lately has it been possible to establish one. It is possible that such a one may be based on the recent work of Raoult, who has shown that the melting-point of a pure compound is always lowered and its boiling-point raised by the addition of a small quantity of some dissimilar substance. But it is important to realise that a satisfactory *experimental distinction* is still a desideratum, and that the only definition that we can give of a compound to distinguish it from a mixture is a theoretical one based on the consideration of molecules.

9. *The Atomic Weight of Carbon.*[2] *By* Professor J. A. WANKLYN.

Members of this Section who, like myself, a third of a century ago were at that time charged with the responsibility of teaching chemistry to the students of a University will have a lively recollection of the incidents attendant on the change of notation at that period. The controversies of that day evolved, as will be remembered, a short and easy method of arriving at the molecular weight of a chemical substance, and likewise a short and easy method of finding the atomic weight of an element.

In Kekulé's words, very slightly modified, these methods were as follows:—

'Defining *standard volume* (or, as it was called, the standard two volumes) as *that volume* which is occupied by *two grammes* of *hydrogen* at a given suitable temperature and pressure, we were told that, if we would know the molecular weight of any chemical substance, we must ascertain how many grammes of the substance were required to fill the standard volume with the vapour of the substance, and that that number was the molecular weight. And the atomic weight of an element was to be found by observing what was the very least quantity of that element ever entering into the standard volume filled with a compound of that element.'

Having laid down the law much in that style, advocates of the new notation forthwith proceeded to make the practical application by noting that the least number of grammes of carbon ever occurring in the standard volume of any carbon compound was 12—*ergo*, the atomic weight of carbon is 12.

It was at the same time incidentally noted that in all those cases where more than 12 grammes of carbon was found in the standard volume, the number was either 24 or 36, or some other multiple of 12. And so the matter has rested until the present day.

I have now to announce that, as the result of most laborious investigation carried on conjointly with my friend and colleague, Mr. Cooper, there exists a multitude of carbon compounds wherein the quantity of carbon in the standard volume is not a multiple of 12, but is a multiple of 6. And the consequence follows that the atomic weight of carbon is 6, as was commonly believed by chemists a third of a century ago.

10. *Popular Method for the Estimation of Carbon Dioxide in the Air.*
By J. B. COHEN, *Ph.D., and* G. APPLEYARD, *Yorkshire College.*

The method consists in determining *the time* required to precipitate the lime in dilute lime water containing an insufficient quantity of lime to unite with all the CO_2 present.

Phenolphthalein is used as indicator, and the end of the reaction is determined by noting the point at which the liquid becomes decolourised.

A 22-ounce stoppered bottle is used with 10 c.c. of lime water made from saturated lime water, diluted 100 times with distilled water. One-third of a c.c.

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[1] *Nature*, June 14, 1894.

[2] See *Phil. Mag.*, May 1894, p. 495.

of phenolphthalein solution is added, which is prepared by dissolving ·2 grm. of phenolphthalein in 100 c.c. of equal volumes of alcohol and water.

Time	Condition of the Air
Under 3 minutes	Bad
Above 3 and under 5 „	Fair
Above 5 „	Good

11. *On the Diffusion of very Dilute Solutions of Chlorine and Iodine.* *By* A. P. LAURIE.

TUESDAY, AUGUST 14.

The following Papers and Report were read:—

1. *Investigations on Tautomerism.* *By* Professor W. J. BRÜHL.

2. *On Ortho-dinitroso Derivatives of the Aromatic Series.* *By* Professor E. NOELTING, *Mulhouse, Alsace.*

In a paper jointly published about two years ago by Messrs. Grandmougin, Michel, and myself, the fact has been mentioned that ortho-nitrodiazobenzeneimide, upon being heated with water or distilled with steam, evolved nitrogen, and that finally a new body fusing at 70°–71° was produced.

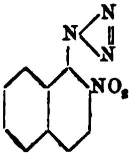
A recent investigation of that body, undertaken in collaboration with Dr. Karl Kohn, has proved its composition to agree with the formula $C_6H_4N_2O_2$, and the determination of its molecular weight gave numbers corresponding to this simplest formula and not to that of a polymere.

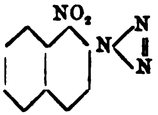
The action of reducing agents resulted in the formation of ortho-phenylenediamine.

These facts render it probable that the new body is ortho-dinitroso-benzene, a para-isomere of which had already been made known by Nietzki. It was produced by the oxidation of para-quinone-dioxime. The analogous oxidation of ortho-naphto-quinone-dioxime into the corresponding ortho-dinitroso-compound has, some time before Nietzki, been carried out by Ilinski. This oxidation is rendered evident by the following formula:—

$$C_{10}H_6 \langle {NOH \atop NOH} + O = H_2O + C_{10}H_6 {NO \atop NO}$$

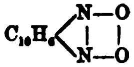
Now the investigation of Mr. Kohn and myself on the products of decomposition of the two ortho-nitronaphtalenediazoimides





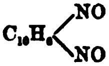
by heat, has proved the identity of the products thus obtained with the ortho-dinitroso compounds described by Ilinski.

Ilinski has proposed for his compound the formula



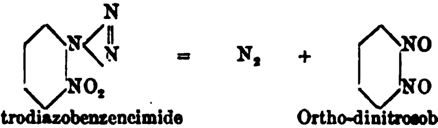
$$C_{10}H_6\left<\begin{matrix}N-O\\ |\quad\ |\\ N-O\end{matrix}\right.$$

The formula



$$C_{10}H_6\left<\begin{matrix}NO\\ NO\end{matrix}\right.$$

analogous to that of Bamberger's nitrosobenzene, is however also possible. No conclusive argument can be adduced in favour of either of them, but, beyond all doubt, our benzene derivatives must have the same constitution as Ilinski's naphthalene compounds. The reaction then proceeds according to the equation



Ortho-nitrodiazobenzeneimide Ortho-dinitrosobenzene

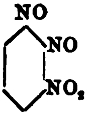
A convenient method of obtaining dinitroso derivatives from the corresponding ortho-diazoimides consists in heating the latter in a solution of glycerine at temperatures ranging from about 100° to 120°. When the evolution of nitrogen has ceased, water is to be added and the nitroso-compound thus precipitated is filtered off. By crystallisation from boiling alcohol it may be easily obtained in a state of perfect purity.

Ortho-dinitrosobenzene crystallises from its aqueous solution in needle-shaped crystals, from alcohol in plates, fusing at 70°–71°. It is sparingly soluble in water, easily in alcohol, ether, &c.

It sublimes readily, and may be volatilised in a current of steam. The odour of its vapour is slightly irritating, and resembles in a dilute state that of nitrobenzene.

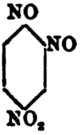
When heated, either with nitric acid of 65 per cent. on the water bath, or treated with concentrated nitric acid at 0° in sulphuric acid solution, it yields a mono-nitro derivative, crystallising in yellow needles; fusing-point 143°.

This mono-nitro derivative has the constitution

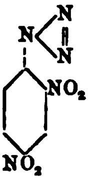


as, by reduction, it yields the known 1. 2. 3, triamidobenzene.

We have also obtained an isomeric compound—

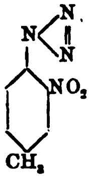


by decomposing the dinitrodiazobenzeneimide

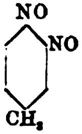


in the same manner.

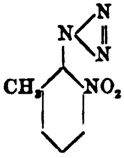
By the same process, ortho-nitrotoluoldiazoimide



yields dinitrosotoluene



On the other hand, the diazoimides



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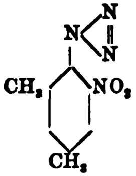
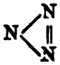


in which a methylic group occupies an ortho-position in respect of the



group, have hitherto resisted every attempt of decomposition by heat, from some cause yet to be investigated.

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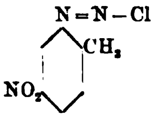
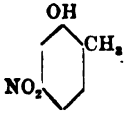
3. *On the Formation of Indazol Derivatives from Aromatic Diazo-compounds.*

By Professor E. Noelting, *Mulhouse, Alsace.*

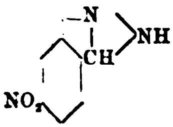
Professor Witt, Dr. Grandmougin, and myself showed a few years ago that the diazo-derivative of nitro-orthotoluidine, fusing-point 107°



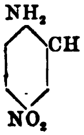
when heated with water, not only yields the corresponding nitrocresol

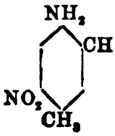


but in about equal quantity a new body, which we proved to be nitro-indazol,



We also found that the diazo-derivatives of 1. 2. 4, nitrotoluidine and 1. 3. 4. 5, nitroxylidine



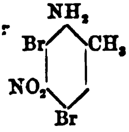


did not undergo a similar decomposition, but were exclusively transformed in the corresponding phenols.

In collaboration with two of my pupils, Messrs. Lorber and Gurwitsch, I have studied the decomposition of the diazo-compounds of several other nitrated amines, containing the methylic and the amido-groups in the ortho-position.

Some of them yielded indazols, while others were only transformed into phenols.

The indazol-yielding nitro-derivatives were



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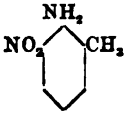

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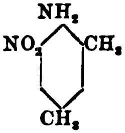

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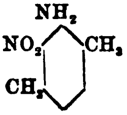

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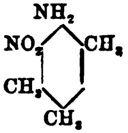
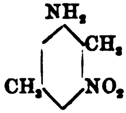
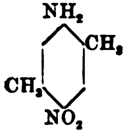


V.

whilst





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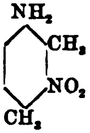
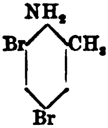
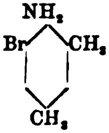


only produced phenols.

In the case of I., II., and IV., the yield of indazol was a very large one, about 90 per cent.; III. and V., on the other hand, gave more phenol than indazol.

Not only is the presence of the nitro-group advantageous to the formation of indazols, but also the halogens, and, in some measure, the sulpho-groups act in the same manner; for instance, the diazo-compounds of





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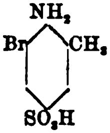
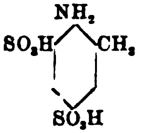
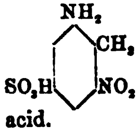


are readily transformed into the corresponding indazols, and



yields about 30 to 40 per cent.; but



gives only the nitro-cresol-sulpho acid.

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4. *On some New Colouring Matters.* *By* Dr. H. CARO.

5. *On the Tartrarsenites.*

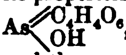
By G. G. HENDERSON, *D.Sc., M.A., and* A. R. EWING, *Ph.D.*

Arsenious oxide dissolves readily in a boiling solution of sodium hydrogen tartrate, and on concentration and cooling a compound of the formula $C_4H_4O_6AsONa.\ 2\frac{1}{2}$ Aq. crystallises out in aggregates of needles or prisms. The salt is quite stable when dry, and may even be heated for several hours at 185° without undergoing further change than loss of water of crystallisation. It has a sweetish, not unpleasant taste, and is easily soluble in water, but it appears to be decomposed slightly by a large excess of water. It crystallises from dilute alcohol in colourless plates.

The corresponding ammonium salt, $C_4H_4O_6AsONH_4.\ \frac{1}{2}$ Aq., which is prepared in a similar way, crystallises in small glistening needles which are easily soluble in water. The crystals effloresce slowly, and appear to undergo partial decomposition on standing for some time.

The potassium salt is not so easily prepared, owing to its instability in aqueous solution. It is obtained by adding arsenious oxide to a boiling concentrated solution of potassium hydrogen tartrate so long as it dissolves, filtering, cooling the filtrate, and then adding two volumes of alcohol to it. The white, finely crystalline precipitate which is formed is washed with alcohol and dried on a porous plate. Analysis of this compound gave results agreeing fairly well with the formula $C_4H_4O_6AsOK.$ Aq. When the salt is treated with water, even in the cold, it decomposes into arsenious oxide and potassium hydrogen tartrate, but it may be recrystallised from dilute alcohol, from which it separates in long needles. Slight decomposition occurs in this case also.

When a dilute solution of barium chloride is mixed with a dilute solution of the sodium salt, delicate glistening needles of the barium salt are gradually formed. It has the formula $(C_4H_4O_6AsO)_2Ba.$ Aq., and is only slightly soluble in hot water. It is decomposed to some extent by boiling with much water. The corresponding strontium and calcium salts are obtained in a similar way, but the mixed solutions are boiled for a short time. They crystallise in small shining cubes, apparently isomorphous, and are more soluble than the barium salt. Other compounds of this series have not yet been prepared.

All of the compounds described above are decomposed by excess of mineral acids, with liberation of arsenious oxide. If, however, the salt is kept in excess, a substance is obtained in solution which has the properties of an acid, but which has not been isolated owing to its instability. When the barium salt, suspended in water, is decomposed by sulphuric acid (taking care to keep the salt in excess), barium sulphate is precipitated and a clear solution is obtained, which remains unaltered even after standing for several weeks. The solution has a strong acid reaction, but contains no free sulphuric acid, and with hydrogen sulphide it gives a copious precipitate of arsenious acid. If heated, or allowed to evaporate spontaneously over sulphuric acid, or mixed with alcohol, it is decomposed into arsenious oxide, which precipitates, and tartaric acid, which remains in solution. It undergoes the same change at once if a drop or two of a mineral acid is added. It decomposes the carbonates of the alkalies and of the alkaline earths, carbon dioxide being evolved, and the salts described above being formed. A quantitative examination of the solution showed that it contained exactly the quantity of arsenic required on the assumption that a substance of the formula $AsC_4H_5O_7$ was present. It may be concluded, therefore, that there is a definite compound of this composition in the solution, and that it is stable at ordinary temperatures if the solution be not too concentrated. Taking its properties into account, this substance may be regarded as a tartrarsenious acid  $As\begin{smallmatrix}\diagup C_4H_4O_6\\ \diagdown OH\end{smallmatrix}$, *i.e.*, as a derivative of the hypothetical orthoarsenious acid $As(OH)_3$, and the compounds described above may be considered to be the salts of tartrarsenious acid, or the tartrarsenites.

Arsenic acid and various acid oxides likewise appear to form definite compounds when treated with the acid alkaline salts not only of tartaric acid but also of other organic oxyacids, but the investigation of this subject has not proceeded far enough to justify the publication of results.

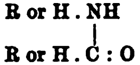
6. *On the Constitution of the Acid Amides.*

By J. B. Cohen, *Ph.D., Yorkshire College.*

Formation of the Acid Amides.—These compounds are usually obtained by three methods, to which the following equations are assigned:

1. $R \text{ or } H.NH_2 + R \text{ or } H.CO_2H = R \text{ or } H.NH.CO.R \text{ or } H + H_2O$
2. $R \text{ or } H.NH_2 + R.COCl = R \text{ or } H.NH.CO.R + HCl$
3. $R \text{ or } H.NH_2 + R \text{ or } H.CO_2R = R \text{ or } H.NH.CO.R \text{ or } H + R.OH$

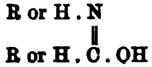
In 2 and 3 the mode of formation would point to the following constitution for the acid amides, which until recently has been generally accepted:



$$\begin{array}{c} R \text{ or } H.NH \\ | \\ R \text{ or } H.C:O \end{array}$$

Carbonyl formula.

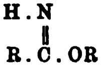
The first equation might be construed so as to yield a body of the constitution



$$\begin{array}{c} R \text{ or } H.N \\ \| \\ R \text{ or } H.C.OH \end{array}$$

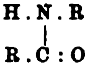
Hydroxyl formula.

Derivatives of this class have actually been obtained by Pinner and others, and termed imido-ethers, and are therefore isomeric with derivatives of the substances having the first formula:



$$\begin{array}{c} H.N \\ \| \\ R.C.OR \end{array}$$

Imido ether.



$$\begin{array}{c} H.N.R \\ | \\ R.C:O \end{array}$$

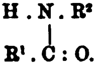
Alkyl amide.

Evidence upon which the choice of formula of the acid amide itself rests is of a very unsatisfactory kind.

The action of conc. HCl, conc. NaOH, PCl_5, P_2O_5, or Br would satisfy either formula.

One reaction appears definitely in favour of the *carbonyl* formula, whereas there are two which point equally distinctly to the *hydroxyl* formula.

Caustic soda and sodium ethylate unite with a few acid amides to form Na derivatives, in which the Na may be replaced by an alkyl group by the action of alkyl iodide, and yields a compound in which the new group is undoubtedly attached to the N atom.



$$\begin{array}{c} H.N.R^2 \\ | \\ R^1.C:O. \end{array}$$

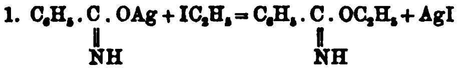
On the other hand, many acid amides unite with silver oxide to form silver compounds in which one atom of H is replaced by Ag, and these bodies treated with alkyl iodide yield the isomeric imido-ethers.

Beckmann's reaction, which consists in a molecular change produced by PCl_5 and other reagents on ketoximes forming isomeric acid amides, points at least to the intermediate formation of a compound of the *hydroxyl* formula.

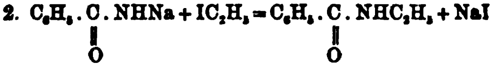
Since working on the aromatic amides it has frequently struck me as curious that of the series formanilide, acetanilide, &c., including benzanilide and oxanilide, the first—formanilide—should possess chemical and physical properties so totally different from the others of the series.

Formanilide crystallises in long prisms from alcohol, whereas the others, including benzanilide, form glistening plates all so similar in appearance that it would be impossible to identify them by their exterior alone. Formanilide, of which the formula is usually written $C_6H_5NH.COH$, yields with NaOH and Ag_2O, Na and Ag compounds, which none other of the series do. This evidently points to a fundamental difference in constitution.

Recent Views on the Constitution of the Acid Amides.—Tafel and Enoch showed that the Ag compound of benzamide differs from the Na compound by the fact that by the action of alkyl iodides the former yielded the imido-ether and the latter the isomeric alkyl amide thus:



$$1.\ C_6H_5.\underset{\underset{NH}{\|}}{C}.OAg + IC_2H_5 = C_6H_5.\underset{\underset{NH}{\|}}{C}.OC_2H_5 + AgI$$



$$2.\ C_6H_5.\underset{\underset{O}{\|}}{C}.NHNa + IC_2H_5 = C_6H_5.\underset{\underset{O}{\|}}{C}.NHC_2H_5 + NaI$$

and Comstock shortly afterwards showed that similar reactions occurred in the case of formanilide. Formanilide was therefore regarded as an example of tautomerism; a view which is now generally held in regard to the constitution of the acid amides.

Leaving for the present the consideration of the Na compounds of the amides, I will take the larger class of acid amides in which an atom of hydrogen is replaceable by an atom of Ag.

The following form Ag compounds, and the solids crystallise in needles or prisms:

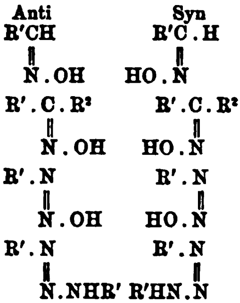
$H.CO.NH\,Ag$	Formamide.
$CH_3.CO.NH\,Ag$	Acetamide.
$CH_3.CO.N(CH_3)\,Ag$	Methyl acetamide.
$CH_3.CO.N(C_2H_5)\,Ag$	Ethyl acetamide.
$H.CO.N(C_6H_5)\,Ag$	Formanilide.
$C_6H_5.CO.NH\,Ag$	Benzamide.
$C_6H_5.CO.N(C_2H_5)\,Ag$	Ethyl benzamide.

The following do not form Ag compounds, and crystallise in plates:

$CH_3.CO.N(C_6H_5)H$	Acetanilide
$C_2H_5.CO.N(C_6H_5)H$	Propionanilide
$C_3H_7.CO.N(C_6H_5)H$	Butyranilide
$C_6H_5.CO.N(C_6H_5)H$	Benzanilide
$(C_6H_5)HN.CO.CO.N(C_6H_5)H$	Oxanilide

In order to account for the different properties of the two groups, we must fall back upon Hantzsch's researches on the stereo-isomerism of the nitrogen compounds.

Hantzsch's Theory.—Hantzsch has shown that bodies of the following general formulæ exist in two modifications:



	Anti	Syn
1. Aldoximes	$\begin{array}{l}R'CH\\ \ \|\\ N.OH\end{array}$	$\begin{array}{r}R'C.H\\ \|\ \ \ \\ HO.N\end{array}$
2. Ketoximes	$\begin{array}{l}R'.C.R^2\\ \ \ \ \|\\ \ \ N.OH\end{array}$	$\begin{array}{r}R'.C.R^2\\ \|\ \ \ \\ HO.N\ \ \ \end{array}$
3. Diazobenzenes	$\begin{array}{l}R'.N\\ \ \ \ \|\\ \ \ N.OH\end{array}$	$\begin{array}{r}R'.N\\ \|\\ HO.N\end{array}$
4. Amidoazobenzenes	$\begin{array}{l}R'.N\\ \ \ \ \|\\ \ \ N.NHR'\end{array}$	$\begin{array}{r}R'.N\\ \|\\ R'HN.N\end{array}$

The two modifications vary in stability according to the relative attraction of the groups.

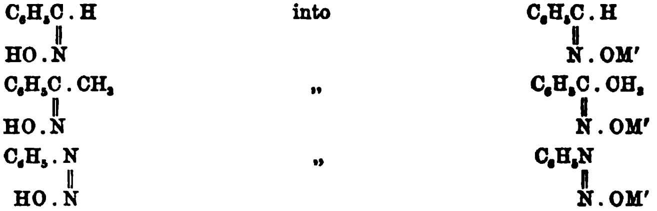
The following is the order of attraction of various radicals for the OH group, according to Hantzsch:

$$CO_2H.CH_2;\ CO_2H;\ C_6H_5;\ C_6H_4X;\ C_4H_3S;\ C_nH_{2n+1};\ CH_3$$

The first attract and the last repel. The group C_6H_5 also repels NHR'.

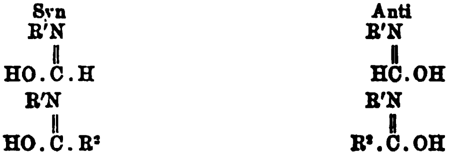
This attraction may be reversed in certain of the metallic compounds of the first three groups, and by the action of a metallic oxide the one configuration is converted into the second more stable one.

Thus NaOH or Na_2CO_3 convert



$$\begin{array}{ccc} \begin{array}{l} C_6H_5C.H \\ \| \\ HO.N \end{array} & \text{into} & \begin{array}{l} C_6H_5C.H \\ \| \\ N.OM' \end{array} \\ \begin{array}{l} C_6H_5C.CH_3 \\ \| \\ HO.N \end{array} & ,, & \begin{array}{l} C_6H_5C.CH_3 \\ \| \\ N.OM' \end{array} \\ \begin{array}{l} C_6H_5.N \\ \| \\ HO.N \end{array} & ,, & \begin{array}{l} C_6H_5N \\ \| \\ N.OM' \end{array} \end{array}$$

Application of the Theory to the Acid Amides.—Suppose we reverse the configurations 1 and 2, we get a formula which is capable of forming two configurations:

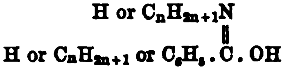


$$\begin{array}{cc} \text{Syn} & \text{Anti} \\ \begin{array}{c} R'N \\ \| \\ HO.C.H \end{array} & \begin{array}{c} R'N \\ \| \\ HC.OH \end{array} \\ \begin{array}{c} R'N \\ \| \\ HO.C.R^2 \end{array} & \begin{array}{c} R'N \\ \| \\ R^2.C.OH \end{array} \end{array}$$

These formulæ will fully account for the constitution of the acid amides.

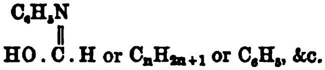
Before proceeding to apply the theory, I will assume that the acid amides, which form Ag compound and crystallise in prisms, belong to the 'anti,' and those which do not, belong to the 'syn' configuration, and crystallise in plates. We can now predict which of the acid amides belong to the former class and which to the latter group.

1. All the acid amides derived from ammonia or fatty amines must be 'anti' compounds of the general formula



$$\begin{array}{r} \text{H or } C_nH_{2n+1}N \\ \| \\ \text{H or } C_nH_{2n+1} \text{ or } C_6H_5.C.OH \end{array}$$

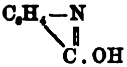
2. Bodies derived from aromatic amines must have the 'syn' configuration:



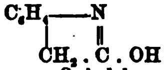
$$\begin{array}{l} C_6H_5N \\ \| \\ HO.C.H \text{ or } C_nH_{2n+1} \text{ or } C_6H_5, \&c. \end{array}$$

Formanilide forms the only exception. This substance should belong to Group 2, but evidently belongs to Group 1. The other modification, which should be easily obtainable, will crystallise in plates, and will not form an Ag compound without reversal into the 'anti' form.

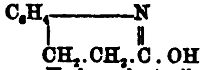
In anthranil, oxindol, and hydrocarbostyril, we have inner acid amides corresponding to the first three anilides. In these compounds it is obvious that the hydroxyl group must occupy the anti-configuration, and should unite with silver oxide and crystallise in prisms. This is the case, although in anthranil the Ag compound rapidly undergoes reduction:



Anthranil

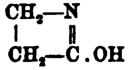


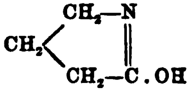
Oxindol



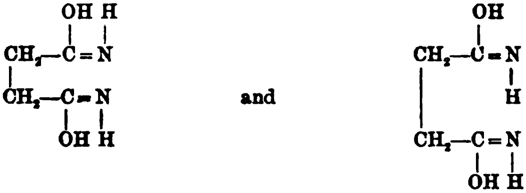
Hydrocarbostyril

The same principle may be applied to the closed chains in the fatty compounds, which should give stable Ag compounds:





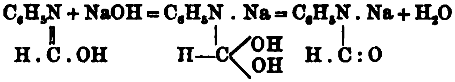
It also accounts for cases of isomerism, such as the two succinamides, which will probably have the configurations



Formation of the Sodium Compounds.—In the course of numerous attempts to prepare pure Na acetanilide, one experiment gave an unexpected result, and it appears to me not only to bear out the above view of the constitution of these bodies, but to throw some light on the formation of the sodium compounds.

If acetanilide is dissolved in dry ether, and one molecule of solid sodium methylate is added, the liquid becomes turbid, and a compound of the formula $C_6H_5N . C(OH)CH_3 . CH_3ONa$ separates out in needles. The two molecules are very loosely attached, and the acetanilide may be easily dissolved out from the other substance. The formation of this compound points to the following:

1. Acetanilide is an unsaturated compound.
2. The formation of the sodium compounds in the case of anti compounds is preceded by the formation of addition compounds, with subsequent loss of one molecule of water, thus:



$$\underset{H.C.OH}{\underset{\|}{C_6H_5N}} + NaOH = \underset{H-C\langle^{OH}_{OH}}{\underset{|}{C_6H_5N}} . Na = \underset{H.C:O}{\underset{|}{C_6H_5N}} . Na + H_2O$$

The experimental part of the work has been carried out in conjunction with Mr. Archdeacon, and will shortly be communicated to the Chemical Society.

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7. *Report of the Committee on the Bibliography of Spectroscopy.*
See Reports, p. 161.

WEDNESDAY, AUGUST 15.

The following Reports and Papers were read:—

1. *Report of the Committee on the Action of Light on Dyed Colours.*
See Reports, p. 238.

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2. *Report of the Committee on Isomeric Naphthalene Derivatives.*
See Reports, p. 268.

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3. *A Discussion took place on* Dr. J. B. COHEN'S *Paper on the Constitution of Acid Amides.*—See p. 625.

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4. *On Certain Phenomena occurring during the Evaporation of Salt Solutions. By* Dr. W. MEYERHOFFER, *Vienna.*

When a solution is partially evaporated it is not necessarily the case that the solid dissolved salts are also precipitated. From the closer examination of what occurs when such a solution is evaporated, the four following cases may be distinguished:

(1) Solutions of a single salt.

(2) Solutions with two or more salts, all of which contain the same acid or basic radical, and form neither double salts nor isomorphous mixtures.

(3) Two salts that are in a condition to form a double salt.

(4) So-called 'reciprocal' salts, *i.e.*, salts which can be formed from two acids and two bases.

Cases 1 and 2 present nothing calling for special notice. In the case of 3, it is shown under what conditions a pure double salt crystallises out of the solution. Similarly, in the case of 4, instances are discussed in which either two or three salts result by evaporation, and an account of new experiments with $NH_4Cl + NaNO_3$ in this relation is given. Lastly, the study of the occurrences which are discussed in the paper is recommended in respect to many technical processes, and the formation of natural salts.

5. *On some Derivatives of Camphene.* *By* J. E. MARSH *and* J. A. GARDNER.

6. *On Fluorene Diacetate.*

By Professor W. R. HODGKINSON *and* A. H. COOTE.

In some previous communications to the Chemical Society by one of us, halogen and other derivatives of fluorene have been described. With the exception of diphenylenketone, there is no derivative in which it is for certain known that the methylenic hydrogen is replaced. When solutions of fluorene, dibenzyl or acenaphtene are acted upon by chlorine, bromine, &c., substitution invariably takes place in the benzenoid nucleus.

From the results of some experiments made by one of us on the sulphonates of fluorene and acenaphtene dissolved in strong H_2SO_4, it appeared probable that dry chlorine might act upon these hydrocarbons in the absence of a solvent, and perhaps at some high temperature in a similar manner to its action on toluene, &c.

Experiment proved this to be the case.

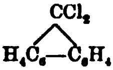
The hydrocarbons were dried and treated with very dry chlorine at the ordinary room temperature, and also at or about the boiling-point of the respective hydrocarbons. Action commenced immediately, and a tendency was noticed for the chloride produced to distil over in the current of chlorine.

The action is, however, not quite confined to the methylenic hydrogen, for the chlorides first produced act as solvents for the still unacted-upon fluorene or acenaphtene, and some substitution in the benzene nucleus takes place. The amount of this can be reduced by letting the chlorine act rapidly.

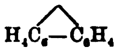
By careful distillation under reduced pressure it is possible to effect a partial separation. A better plan is to dissolve in absolute alcohol, and fractionally crystallise by cooling with a CO_2 alcohol bath.

From fluorene the following bodies appear to be produced:—

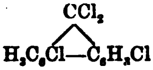
I.



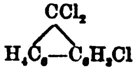
II.



III.



IV.



Acenaphtene is converted almost entirely into a dichloride. None of the chlorinated fluorene products gives diphenylenketone when oxidised under the same conditions as produce diphenylenketone from fluorene.

One fraction of the chlorinated fluorene which distilled under about 300 mm. at 320° to 330° C. gave 29°·52 per cent. Cl; the calculated amount for $C_{13}H_8Cl_2$ is 30·23 per cent.

A diacetate was prepared from this by digesting with alcoholic potassium acetate. On analysis this gave 71·23 per cent. carbon and 3·92 hydrogen—$C_{13}H_8.(CH_3CO_2)_2$ requires 72·3 C and 4·9 H. This product boiled at 326° to 330° C. at 760 mm. pressure.

A large quantity of the crude chlorination product was digested with acetate. From the result several bodies have been separated by fractional distillation, a comparatively easy process, since the acetates are much more stable than the chlorides.

A fraction at 322° C. gave 72·61 C and 4·28 H. Therefore nearly pure diacetate.

We have some proof that a chlormonacetate is also formed as well as some chlorinated diacetates. Of these we have isolated one product, which on analysis gives (I) 11·01 per cent. Cl; (II) 11·4 per cent. Cl: $C_{13}H_7Cl.(C_2H_3O_2)_2$ requires 11·2 per cent. Cl. It melts at about 60° C.

Acenaphtene diacetate distils at about 290° C. and melts at 46°.

We are obtaining larger quantities of these acetates—fluorene, acenaphtene, and dibenzyl—in order to study them further.

7. *Interim Report of the Committee to inquire into the Proximate Chemical Constituents of the various kinds of Coal.*—See Reports, p. 246.

8. *Interim Report of the Committee on the Properties of Solutions.*

9. *Report of the Committee for preparing a new Series of Wave-length Tables of the Spectra of the Elements.*—See Reports, p. 248.

SECTION C.—GEOLOGY.

PRESIDENT OF THE SECTION—L. FLETCHER, M.A., F.R.S., F.G.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

WITH an anxious desire to conform to the traditions of the past, I have sought in the Reports of the Association for guidance in my present difficulty, and, doing so, have remarked that it is customary for a president, on first taking the Chair, to express a deep sense of unworthiness for the position to which he has been called. My first duty, then, seemed a simple and obvious one; till I further remarked, to my dismay, that the more able and distinguished the President the more humble have been the terms in which such expression has been made. Hence I feel that it may appear to you presumptuous on my part if I myself make any apology at all, and it would doubtless imply a claim to the highest ability and distinction were I to make that humble apology which would be really appropriate to the circumstances of the case.

Instead, however, of dispensing with the apology altogether—that might be too radical an innovation to be introduced this year—I propose, with your sanction, to make a lesser change, and merely to defer the apology from the first to the last day of our session. I may reasonably hope to be able, at that later stage, to make clear to you, by simple reference to your own experience during the Meeting, that the apology I shall then feel it my duty to make is of no merely formal character, but one which is worthy of your serious consideration.

I would ask that in the meantime your continuous sympathy be extended to one who now finds himself in a position he would have been the last to seek, and whose ordinary duties in life involve speechless communion with inanimate Nature rather than oral address to an assembly of fellow-workers.

This matter of apologetic precedent being thus disposed of to our common satisfaction, I should have preferred to have brought the delay of the normal business of the Section to an immediate end by calling upon the author of the first paper to now address you. Such, indeed, was the ordinary course of procedure in the earlier, and perhaps presidentially happier, years of the Association; but the occasion of taking the chair having been once seized upon, in absence of mind, by a mathematical president for the delivery of an address, it has come about that each president now feels it his bounden duty, not merely to give an address, but to make that address at least as long and at least as elaborate as any which has preceded it.

We shall all agree that a presidential address, if there is to be any at all, should be elaborately short and elaborately simple; it should deal, not with technical details such as are only intelligible, even to the president himself, after much study, but with general principles such as can be immediately grasped by every member of an audience: an opening address which is so long that it can be only partly read, and is written to be studied afterwards in the Reports of the Association, may more appropriately be issued as an ordinary memoir. I make this remark to safeguard the interests of future audiences, for the example of technicality which I am now about to set is one which I cannot recommend my successors to follow.

As for subject, a record of recent scientific progress is always interesting and instructive, and immediately suggests itself as the natural basis of a presidential address. But seeing that, so lately as in February last, the geologists have had the advantage of an address from the retiring president of their Society, Mr. Hudleston, which has been virtually exhaustive in its survey and criticism of the British geological work of the last seven years, the time has scarcely yet arrived when a continuation of that review by the president of this Section can be of service to the members of the Association.

For this and other still more weighty reasons which I need not directly mention, I feel myself debarred from undertaking any review of recent geological discovery, and shall therefore ask you to allow me to confine myself, in the remarks it is my duty to make, to a science which, though it is not purely geological, and in the Reports of the Association has long been associated with the science of another Section, Chemistry, is yet very closely related to the science of our own Section, Geology.

I trust that the members of the Section of Chemistry and Mineralogy are now so closely engaged in another place that they will fail to discover, or at any rate to resent, the technical trespass on their own domain: as for yourselves, you will perhaps be more ready to pardon the temporary excursion from the field of pure Geology if I remind you that the Fathers of the Geological Society defined their sole object to be 'the investigation of the mineral structure of the Earth;' and I may add, if further defence be desired, that in the first half of this century the relationship of Mineralogy and Geology was so intimate that it was possible for a Section of the British Museum to be long officially designated 'the Department of Mineralogy, including Geology.'

I was the more impelled to choose this subject for our consideration to-day when I reflected that pure Mineralogy has been hitherto almost completely out of sight, and therefore probably out of mind, at the Meetings of the Association. It is true that at the first Meeting, held sixty-three years ago, Mr. Whewell, then the Professor of Mineralogy at Cambridge, was invited to draw up a report on the state of knowledge of the science, and that his report was submitted and printed in the following year. But in the course of the sixty-three years during which the Association has flourished, it has chanced that a devotee of pure mineralogy has on only one occasion, that of 1862, been seated in a presidential chair; and since at that time presidential addresses had not yet come to be regarded as necessary to the existence of the Sections, Professor Miller, with admirable discretion, refrained from inflicting a mineralogical dissertation on an audience which, he had reason to presume, must consist entirely, or almost entirely, of chemists.

Perhaps you might be tempted to think that the want of prominence of the mineralogists at our previous Meetings has been due to a becoming sense of modesty resulting from the study of that science: this would be a mistake. The fact is that a mineralogical memoir, dealing largely with numerical quantities and involving great variety of experiment and technicality, may be read and studied, but should never be heard; like the mathematician, the mineralogist despairs of making clear to an audience, especially a mixed one, the bearing of any researches which have been made in his subject. But now that sixty-two years have elapsed since the issue of Professor Whewell's Report, the time has perhaps at length arrived when it is advisable, notwithstanding the difficulties surrounding an oral treatment of Mineralogy, to attempt to give to the Association a faint idea of the present position of the study of the subject. And if most of my hearers find that the remarks are too technical to be in any great part intelligible, let them console themselves with the reflection that, if the future at all resembles the past, only Shalum and Hilpa can have to endure again that particular kind of *mauvais quart d'heure* which is to precede the Geological Feast of to-day.

The Systems of Crystallisation.—At the time of the publication of Professor Whewell's Report it had already been established by the researches of Romé de l'Isle, Haüy, Mohs, and Weiss that the position of any single face of any crystal can be exactly defined by means of two sets of quantities: firstly, three lines or axes, of which the lengths and mutual inclinations are characteristic of the substance itself; secondly, three whole numbers or indices, rarely rising higher in magnitude than the number 6; further, an empirical arrangement of crystals into systems had been based by Mohs and Weiss on the relative lengths and inclinations of the axes. And a long series of observations of the optical characters of crystals had revealed to Brewster the fact that the boundaries of the classes of optically isotropic, uniaxal and biaxal crystals form part of the boundaries of the empirical systems. But whereas only three optical classes of crystals had been recognised, it was certain that there were at least four geometrical systems, and it was a matter of controversy as to whether the independence of two others should not be regarded as geometrically established.

The first important discovery following the issue of Whewell's Report was one which proved that the two doubted systems are natural ones. It was found by Herschel and Neumann that the biaxal crystals are not optically similar, as had hitherto been supposed, but are of three kinds. In crystals of one kind—for example, barytes—the two lines bisecting the angle of the optic axes internally and externally, and a third line perpendicular to both, are constant in direction in the crystal whatever the colour of the light; in a second kind—for instance, selenite—only one of these lines is constant when the colour varies; in a third kind—for instance, axinite—none of the three lines has any constancy of direction. And these three kinds of biaxal crystals correspond exactly in their facial development to the three systems of crystallisation of which the independence had already been asserted by some crystallographers on geometrical grounds. From this time the arrangement of crystals into the six systems has been regarded as a natural one; and the optical method based on the figures seen in plates when examined in convergent polarised light has been in constant use, and is an invaluable aid in the determination of the system of crystallisation.

Crystallographic Notation.—For a simple method of expressing the relative positions of crystal faces by a symbol, crystallographers are infinitely indebted to the late Professor Miller of Cambridge. The symbols introduced by Mohs, Weiss, Lévy, Naumann, and the modification of the latter suggested by Dana, though interesting, are not to be compared for legibility, pronounceability, or utility in calculation, with the simple symbol which is associated with the name of Professor Miller. Though the symbol was not invented by him, he was the one who, so to say, gave it life. He discovered and made known its many advantages; and in his Treatise published in 1839—a treatise which is a masterpiece of mathematical terseness and simple elegance—he gave the methods of crystallographic calculation which render the advantages of the symbol particularly manifest. It may be here remarked that in that treatise the rationality of the anharmonic ratios of any four tautozonal planes of a crystal was first made known, and the property was largely used in the simplification of the methods of calculation: the fact that the fraction was of the kind which had been already termed an anharmonic ratio, however, had escaped the attention of the author.

But the change of a method of notation, like a change in a system of weights and measures, involves such serious practical difficulties that many years passed away before the Millerian symbol received abroad the consideration which it deserved. Now, at last, no Continental text-book of Mineralogy fails to introduce the Millerian indices, even if the symbols of Lévy or of Naumann are given in addition; and it is evident that within a few more years the mineralogist will be completely relieved from the tiresome necessity of translating each crystalline symbol into another form to make it intelligible to him, and the student will be able to make a more advantageous use of the time which has been hitherto devoted to acquiring a mastery over a second and unnecessary form of crystallographic notation. For this result credit is largely due to Professor Groth of Munich, whose adoption of the Millerian symbol in the 'Zeitschrift für Krystallographie' has done much to bring home its advantages to the foreign worker. It is to be hoped that Professor Groth will earn the further gratitude of students by encouraging the adoption of the true Millerian symbol in the still outstanding case of the Rhombohedral System.

Rationality of Indices and the Law of Zones.—It may here be pointed out that, although the importance of zones for the simplification of crystallographic calculation had been recognised by Weiss, it was only later that Neumann proved that the fact that all possible crystal faces can be derived by means of the intersection of zones is a necessary consequence of the rationality of the indices; that, indeed, the law of zones is mathematically identical with the law of rationality. To the same able physicist and mathematician we owe the development of the method of stereographic projection now in common use by crystallographers for the representation of the poles of crystal faces.

Symmetry.—We have said that the recognition of six systems of crystallisation was a result of consideration of the lengths and mutual inclinations of certain lines called axes. Now, it had long ago been remarked that any one face of a crystal is accompanied by certain others similarly related to the geometrically similar parts of what may be regarded as a fundamental figure: such a group of concurrent faces is called a simple form. It came to be recognised, too, that all the faces of such a form can be geometrically derived from any one of them by repetition, according to certain laws of symmetry, and that the same laws of symmetry are binding for every simple form or combination of forms exhibited by crystals of the same substance. Hence it came to be perceived, though very slowly, that the essential differences of the systems of crystallisation are not mere differences of lengths and mutual inclinations of lines of reference, but are really differences of symmetry. Ever since his appointment to the professorship of Mineralogy in this University, now thirty-eight years ago, Mr. Maskelyne has been persistent in directing attention to the importance of symmetry, and such importance now receives universal recognition.

Thirty-two Types of Symmetry in Crystals.—But in each system of crystallisation it becomes necessary to recognise both completely and partially symmetrical types. In the latter, the symmetry is in abeyance relative to various planes or lines which in other crystals of the same system are active as planes or axes of symmetry. But this abeyance of symmetry is itself found to be subject to a law, for all planes or axes of symmetry which are geometrically similar are either simultaneously active or simultaneously in abeyance. By means of this law relating to partial symmetry, it has been inferred that altogether thirty-two types of symmetry are possible in the six crystalline systems.

The possible existence of these thirty-two types of symmetry of crystals is thus an induction from observation: the question naturally arises as to why only these thirty-two exist or are inferred by analogy to be possible. Axes of symmetry are observed round which faces of crystals are symmetrically repeated by twos or threes or fours or sixes; why is it that in crystals no axis of symmetry is ever met with round which the faces are symmetrically repeated by fives or sevens? A few words as to how this most important problem has been attacked and solved may be of interest.

We know that the characters of a crystal relative to any line in it vary with the direction of the line, but are the same for all lines parallel to each other. Such a property will result if we imagine with Bravais that in a crystal elementary particles are arranged at equal distances from each other along every line, and are similarly arranged in all those lines which are parallel to each other; the distances separating particles being, however, in general different for lines which are inclined to each other. Such an arrangement of particles is termed parallelepipedal: space may be imagined to be completely filled with equal and similarly disposed parallelepipeds, and an elementary particle to be placed at every corner or quoin of each. Further, each particle is regarded, not as being spherical, but as having different characters on its different sides; and the particles must be similarly orientated—that is, have similar sides in similar positions.

Now, it will be seen on examination of a model or figure that with such an arrangement any plane containing three particles will contain an infinite number, all arranged at the corners of parallelograms. Further, any such plane will clearly have whole numbers for the indices which fix its position, for along any line the distance between two particles is by hypothesis a whole multiple of the common distance between any two adjacent ones in the same line. Thus the first great crystallographic law—the law of the rationality of the indices—is an immediate consequence.

In the next place, it was found that the possible modes of symmetry of arrangement of the particles of such a system depend on the form of the parallelepiped, and that any possible arrangement of the particles must present a symmetry which is identical with one or other of the six completely symmetrical types already referred to. And calculation shows that any other mode of grouping—a repetition by fives or sevens, for example—round an axis of symmetry, would involve the presence of planes having irrational indices; and this according to the first law is impossible.

The abeyance of symmetry, however, met with in the partially symmetrical types required the aid of an auxiliary hypothesis—namely, that the abeyance of symmetry belongs to the particle itself, and not to the arrangement of the particles.

But the parallelepipedal arrangement imagined by Bravais is unnecessarily special. Our actual observations of physical characters relate not to single lines of particles, but to groups of parallel lines of particles: the identity of character observed in parallel directions is thus not necessarily due to actual identity of each line with its neighbour, but may be due to statistical equality, an equality of averages. If, for example, a plane were divided into regular hexagons, and a particle were placed at each corner of each of these figures, the physical properties of the system of particles would be the same along all lines parallel to each other as far as experiment could decide, and yet the arrangement of the particles in the plane, though possibly crystalline, is not that of a Bravais system. In any straight line passing along the sides of a series of the hexagons, the particles will not be equidistant from each other: they are in equidistant pairs, and the two nearest particles of adjacent pairs are twice as far from each other as the particles of the same pair.

Sohncke accordingly suggested a more general definition than that of Bravais for the regularity of the arrangement, a definition which had been proposed some years before by Wiener—namely, that the grouping relative to any one particle is identical with that relative to any other. This definition admits of the possibility of the hexagonal arrangement just mentioned; further, it allows of the orientation of the particles themselves being different in adjacent lines. Following a mathematical process which had been already employed by Jordan, Sohncke deduced all the possible modes of grouping consistent with the new definition, and for a time was under the impression that the types of symmetry found by him to be mathematically possible are exactly identical with those already referred to; and this without introducing the auxiliary hypothesis relative to partial symmetry of the elementary particles of merosymmetrical crystals, except in cases of hemimorphism. It was, however, pointed out by Wulff, who has himself made valuable contributions to the subject, that though no unknown crystallographic type belongs to such a regular arrangement, one type of symmetry, that presented by dioptase, is missing; and it seems that, in this case at least, the merosymmetry can only be accounted for by the merosymmetry of the particle, or something equivalent to it, if the definition of regularity suggested by Sohncke is to be accepted. It was recognised by Sohncke that each of his point-systems can be regarded as a composite Bravais system, one of the latter being repeated in various positions corresponding with the symmetry of the parallelepiped itself.

More recently, Schönflies has made a more general hypothesis still—namely, that in each substance, whether its crystals be completely or partially symmetrical in facial development, the particles are not of a single kind, but of two kinds, related to each other in form in much the same way as a right-hand glove and a left-hand glove. With this hypothesis he finds that all the thirty-two known types are accounted for without any specialisation of the characters of the particle, and that no other type of symmetry is mathematically possible.

It now only remained to discover that Professor Hessel had already arrived at the thirty-two types of crystallographic symmetry by mathematical reasoning more than sixty years ago; his work, being far in advance of his time, appears to have attracted no attention, and the memoir remained unnoticed till more than half a century after its publication.

Starting from Sohncke's definition of a regular point-system, and proceeding, though independently, by a method which closely resembles that of the regular partitioning of space by Schönflies, Mr. William Barlow has given in a paper just issued a general definition applicable to all homogeneous structures whatever, and has shown that every such homogeneous structure falls into one or other of thirty-two types of symmetry, coinciding exactly with the thirty-two types of crystal-symmetry. He points out that each of those homogeneous structures which possess planes of symmetry or centres of symmetry does so by reason of its having an additional property beyond mere homogeneity, namely, that if we disregard mere orientation, it is identical with its own image in a mirror. Mr. Barlow further discovers that every one of the Sohnckian point-systems can be geometrically constructed by finite repetition of some one of a certain ten of them.

Lord Kelvin, who, with characteristic versatility, has lately enlightened us with his researches on Molecular Tactics, has quite recently attacked another problem of the same group, and has sought to discover the most general form of cell which shall be such that each cell encloses a single point of a Bravais system, while all the cells resemble the parallelepipeds, of which we have already spoken, in being equal, similar, similarly orientated, and in completely filling up space. He finds that in the general case the cell can have at most fourteen walls, which may be themselves either plane or curved, and may meet in edges either plane or curved. Having regard, however, to the limited time at our disposal, we may hesitate before following Lord Kelvin into his curious and many-walled cell.

The deduction of the thirty-two types of symmetry by mathematical reasoning was also made independently by both Gadolin and Viktor von Lang thirty years ago from the law of rationality of indices; while Fedorow points out that the method of deduction recorded in the recent German treatise of Schönflies is remarkably similar to the one independently published by himself in Russia. Both Curie and Minnigerode have also lately given comparatively brief solutions of the problem.

Nor must I omit to mention to you the elaborate memoir dealing with the symmetry of parallelepipedal point-systems which was written by the late Professor Henry Stephen Smith, whose too early death this University has so much reason to deplore. To the outer world he was perhaps best known as one of the most perfect mathematicians of the age, but those who had the good fortune to find themselves among his pupils will always treasure up in their memory rather the kindly courtesy, the warm sympathy of the man, than the genius, however transcendent, of the mathematician.

To sum up this part of the subject—it is now established that a definition of the regularity of a point-system can be so framed that thirty-two, and only thirty-two, types of symmetry are mathematically possible in a regular system, and that these are identical with the types of symmetry that have been actually observed in crystals, or are inferred by analogy to be crystallographically possible.

It remains for subsequent investigators to determine what the points of the system really correspond to in the crystal; according to Schönflies, the physicist and the chemist can be allowed in each crystal absolute control within a definite elementary region of space, and the crystallographer is only entitled to demand that the features of this region are repeated throughout space according to one or other of the thirty-two types of symmetry already referred to; or, what appears to be the same thing, the crystallographer requires mere homogeneity of structure.

Simplicity of Indices.—We have seen that the planes containing points of a regular point-system have rational indices. But there still remains unaccounted for the remarkable fact that the indices of the natural limiting faces, and also of the cleavage-planes of a crystal, are not merely whole numbers, but are in general extremely simple whole numbers. Bravais and his followers have sought to account for this by the hypothesis that both the natural limiting planes and the cleavage-planes are those planes of a point-system which are most densely sprinkled with points of the system. Curie and Liveing, independently of each other, have been led to the same result from considerations relative to capillary constants. Sohncke, however, pointing out that there are many cases—for instance, calcite—where an excellent cleavage-plane is rarely a limiting plane, suggests that his generalised point-system is more satisfactory than a Bravais system in that not only the density of the sprinkling must be had regard to, but also the tangential cohesion of the particles in the plane, and that in his system these may be independent of each other; while Wulff remarks that Sohncke's arrangement is identical with that of Bravais for the anorthic system, where the same objection holds, and he denies the legitimacy of the reasoning by which the hypothesis of a relation between the density of the sprinkling of points on a plane and the likelihood of the natural occurrence of the plane as a limiting face is supported.

Complexity of Indices.—Doubtless, however, crystal faces are observed of which the symbols involve indices far exceeding 6 in magnitude—so complex, in fact, that one is tempted to doubt the rigidity of the experimental proof that indices are necessarily rational. Often, though the numbers are high, their ratios differ by only small amounts from simple ones. A most patient and detailed study of such faces was made for danburite by the late Dr. Max Schuster of Vienna, and the results were brought by him some years ago to the notice of this Section. From careful examination of similar faces in the case of quartz, Molengraaff has been led to conclude that it is extremely probable that such faces are of secondary origin and have been the result of etching: they would in such case correspond, not to original limiting planes, but to directions in which the crystal yields most readily to solvent or decomposing influences.

Optical Characters.—Passing from the purely geometrical characters of crystals to the optical, we may in the first place remark that the relationship between crystalline form and circular polarisation discovered by Herschel in the case of quartz has been generalised since the issue of Whewell's Report. We now know that many crystallised substances belonging to different systems give circular polarisation, and that all of them are merosymmetrical in facial development or structure; further, they belong to types of symmetry which have a common feature, though this is only a necessary, not a sufficient, condition.

The importance of the discovery of the dispersion of the mean lines has already been referred to.

We may recall attention to the fact noticed by Nörremberg, that when cleavage-plates of biaxal mica are crossed in pairs and the pairs are piled one upon another in similar positions, the optical figure yielded by the combination approaches nearer and nearer to that of a uniaxal crystal the thinner the plates and the more numerous the pairs: in the same way, by means of triplets of plates, each plate being turned through one-third of a complete revolution from the position of the preceding one, Reusch found it possible to closely imitate the optical figure of a right-handed or a left-handed circularly polarising crystal.

And it has been observed that repeated combinations of differently orientated parts actually occur in crystals. Large crystals of potassium ferrocyanide, for example, are really composite, and the different parts are differently orientated: on the one hand, a thick slice may give an optical figure which is uniaxal; on the other hand, a thin slice shows two optic axes inclined to each other at a considerable angle.

It has been suggested that the circular polarisation of quartz and other crystals is due to a spiral molecular arrangement corresponding to that of the mica-triplets as arranged by Reusch. Such a spiral arrangement is shown by the points of the corresponding Sohnckian system.

Optical Anomalies.—As already mentioned, we owe to Brewster the establishment of the relation between the optical behaviour of crystals and the systems of crystallisation. But in the course of his long research Brewster met with numerous puzzling exceptions, and to the investigation of the origin of their peculiar optical behaviour he devoted much study; subsequent workers have concurred in expressing their admiration of the accuracy of his observations and descriptions, more especially when regard is had to the extreme simplicity of the apparatus available in those early days.

It was recognised by Brewster that some of these optical anomalies are due to a condition of strain of the crystal, as in the case of the diamond. But in other minerals, as analcime and apophyllite, the hypothesis of strain was not entertained by him: he regarded the crystals as being truly composite and not simple; and, recognising optically different kinds of apophyllite, went so far as to give to one of them the specific name of tesselite by reason of its distinctive characters. Biot, on the other hand, sought to account for this kind of optical behaviour in another way, by the hypothesis of lamellar polarisation: a crystal of alum, for example, he held to be built up of thin laminæ arranged parallel to the octahedral planes, and imagined that light which has traversed such a crystal is polarised by its passage through the aggregation of laminæ in the same way as by passage through a pile of glass plates. But in the latter case there is a frequent passage of the light from air to glass and glass to air, whereas in the case of alum there is no evidence of the existence of atmospheric intervals. Frankenheim sought to overcome this difficulty by the further hypothesis that the successive layers of a composite potassium- and ammonium-alum are of different chemical composition, but such a difference of material would be insufficient for the desired object by reason of the nearness to each other of the refractive indices of alums of different composition. Still, it is a remarkable fact that neither a pure potassium-alum nor a pure ammonium-alum shows any depolarisation-effects at all; these belong only to the alums of mixed composition, and yet there is no visible difference in the physical structure of the crystals of simple and composite material.

An epoch was made in the history of the so-called optical anomalies by the publication in 1876 of an elaborate memoir by Professor Ernest Mallard of Paris, whose death last month deprived Mineralogy of its greatest philosopher. To make the position more clear, we may take as a definite illustration the mineral boracite. In development of faces and magnitude of angles the crystals of this mineral are, as far as measurement with the goniometer can decide, precisely cubic in their symmetry. But an apparently simple crystal of boracite, when examined in polarised light, behaves exactly like a regularly composite body. If the crystal be a rhombic dodecahedron in external development, all the twelve pyramids which can be formed by drawing lines from the centre to the angular points are found to be exactly similar to each other in everything but orientation; and, further, each of them has the optical characters of a biaxal crystal, the optic bisectrix of each individual pyramid being perpendicular to the corresponding base, and thus having a different direction for each of the six pairs of parallel faces of the dodecahedron. Hence Mallard inferred that boracite belongs really, not to the cubic, but to the orthorhombic system, and that its crystallographic elements are so nearly those of a cubic crystal that the molecular structure is in stable equilibrium, not only when different molecules have their similar lines parallel, but also when only approximately similar lines have the same orientation; further, the cubic symmetry of the external form was regarded by him as a consequence of the approximation of the crystallographic elements to those of a cubic crystal and of the variety of orientation of the constituent molecules. Variety of orientation of constituent molecules is, in fact, already recognised in the case of ordinary interpenetrant twins. The variation of optical character in different crystals of the same substance or different parts of the same crystal was then explained as being due to the variation in the number of molecules belonging to each mode of orientation.

According to another view, it was contended that a crystal of boracite is really cubic and simple, but that, like unannealed glass, it is in a state of strain related to the external form. It was replied that the optical characters of such unannealed glass are changed with the change of strain which follows the fracture of the specimen, while those of boracite are unaltered when the crystal is broken. To this it was rejoined that a once compressed gum retains its depolarising character unchanged on fracture of the specimen, and that the same permanence may very well be a character of some strained crystallised bodies.

The controversy, however, passed to a fresh stage when it was discovered that boracite becomes optically isotropic when sufficiently heated, and resumes an optically composite character on cooling. Mallard showed that the temperature at which the change takes place is a definite one, 265° C., and that a definite amount of heat is absorbed or given out during the change of condition.

It is now agreed that boracite is really dimorphous; that above 265° it is cubic in symmetry, below 265° orthorhombic: the only remaining point of controversy as regards boracite seems to be whether the external form owes its cubic symmetry to the crystallisation having taken place at a temperature higher than 265°, and therefore when the structure itself was truly cubic, or at a temperature below 265°, in which case the cubic character of the form would be ascribed to the fact that the orthorhombic constituent particles are so nearly cubic in their dimensions that at any temperature they may by variety of orientation combine to form a structure having practically cubic symmetry, and naturally limiting itself by faces corresponding to such a symmetry.

In exactly the same way leucite and tridymite become respectively optically isotropic and uniaxal when sufficiently heated, and the optical characters then correspond exactly to the symmetry of the external form.

Three years ago Dr. Brauns prepared a most useful summary of the ninety-four memoirs which had up to that time been contributed relative to the much-discussed subject of the optical anomalies of crystals, and added many new experimental results which had been obtained by himself. He concludes that the original view of Mallard—namely, that an optically anomalous structure consists merely of differently orientated particles of the same kind and of symmetry approximating to a higher type—is only applicable to a very limited number of crystals, such as those of prehnite; that dimorphism is the true cause in others, boracite being an example; that in the remaining minerals the cause is strain, which in some of them is due to foreign enclosures, as in the case of the diamond, and in others is due to a molecular action between isomorphous substances, as in the mixed alums and the garnets.

Planes of Gliding.—One of the most startling of crystallographic discoveries was one made by Reusch, who found that if a crystal of calcite is compressed in a certain way each particle springs into a new but definite position, exactly as if the crystal had undergone a simple shear and the particles at the same time had each described a semi-somersault: a simpler method of producing the same result was discovered afterwards by Baumhauer. If only part of the calcite crystal is sheared, the two parts of the structure itself are related to each other in the same way as the two parts of a twin growth; but in general the external form is different from that of a twin, since after the shearing of the material few of the faces retain their former crystallographic signification. The property has since been shown by Bauer, Liebisch, and more especially Mügge, to be a very general one; and doubtless the so-called twin lamellæ met with in rock-constituents have in many cases resulted from pressure during earth-movements long subsequent to the epoch of formation of the crystals. Similar lamellæ have been produced artificially in anhydrite and some kinds of felspar by exposure of the crystals to a high temperature.

Piezo-electricity.—The most remarkable addition to our knowledge of the relation of minerals and electricity has been the recent discovery of the electrification produced by strain (piezo-electricity). It has been shown by J. and P. Curie that if a quartz-plate, with faces cut parallel to the axis and silvered to make them conductive, be strained in a certain direction, the two faces either become oppositely electrified or show no signs of electrification at all, according as the faces of the plate are cut to be perpendicular to the prism-faces, or to pass through the prism-edges. Lord Kelvin says that this result is explicable by electric eolotropy of the molecule and by nothing else, a character which he had suggested for the molecule thirty-four years ago: experiments confirmatory of this hypothesis of the permanent electrification of the molecule were made some time ago by Riecke.

Pyro-electricity.—The development of opposite electricities at different parts of a crystal during changing temperature (pyro-electricity) has long been known in the case of tourmaline. We owe to Hankel a long series of investigations of this kind relative to boracite, topaz, and various other minerals, but it seems to be now established that most of the electrifications observed by means of his method are really piezo-electric, and are due to strains caused by inequality of temperature in different parts of the cooling crystal. A model has been lately made by Lord Kelvin which gives a perfect mechanical representation of the elasticity, the piezo-electricity, and also the pyro-electricity of a crystal.

Electrical Methods.—A delightfully simple method of investigating the difference of electrical condition of the parts of a cooling crystal and of making the distribution of electricity visible to the eye has been invented by Kundt. Mixed particles of (red) minium and (yellow) sulphur are oppositely electrified by their passage through the meshes of a small sieve; falling on the cooling crystal, each particle adheres to the oppositely electrified region, and the electrical condition of the latter is thus immediately indicated by the colour of the adherent powder. Mr. Miers remarks that this method is practically useful as a means of discrimination even when the crystals are extremely minute.

Other Physical Characters.—Of other physical characters much studied since the issue of Whewell's Report, I may recall to you more especially the dilatation of crystals on change of temperature, in which the observations of Mitscherlich have been extended by Fizeau and Beckenkamp; the forms of the isothermal surfaces of crystals, as determined by Sénarmont, and afterwards by Röntgen; the magnetic induction treated of by Faraday, Lord Kelvin, Plücker, and Tyndall; the hardness of crystals for different directions lying in the same faces, by Grailich, Pekárek, and Exner; the elasticity of crystals, investigated by Neumann, Lord Kelvin, Voigt, Baumgarten, and Koch; the distortion of crystals in an electro-magnetic field, by Kundt, Röntgen, and MM. Curie.

Chemical Relations.—In the short time I can reasonably ask you to allow me it is clearly impossible to enter upon any discussion of the increase of our knowledge of the chemical relations of minerals, and to treat of the much-investigated subjects—isomorphism, polymorphism, and morphotropy; nor can I attempt to give you any idea of the advance which has been made towards a natural classification: nor must I mention the experiments which have been made relative to the growth of crystals, the etching of their faces, or their directions of easiest solution.

Systematic Mineralogy.—As regards systematic mineralogy an immense amount of progress has been made. The condition of affairs in 1832 was described by Whewell as follows:—'We have very few minerals of which the chemical constitution is not liable to some dispute; scarcely a single species of which the rules and limits are known, or in which two different analyses taken at random might not lead to different formulæ; and no system of classification which has obtained general acceptation or is maintained, even by its proposer, to be free from gross anomalies.' An idea of the extent of the improvement will be best obtained from a comparison of the first edition of Dana's Treatise, published in 1837, and that treasury of information, the sixth edition, which appeared in 1892. The names of Miller and Descloizeaux are to be honourably mentioned in connection with this detailed work on species. In the interval of time under consideration the number of well-established species has been more than doubled, and the rate at which new species are discovered shows as yet no sign of diminution. In particular, I may remind you of the work which has been done in the correlation of the members of large groups, like the felspars, amphiboles, pyroxenes, scapolites, micas, tourmalines, and garnets. A paper just published by Penfield relative to topaz furnishes an excellent illustration of the important results which are still to be arrived at from a careful study of a common mineral. It has long been known that the mutual inclination of the optic axes of topaz is very different in different specimens, and it has been suspected that the variation might depend on the percentage of fluorine. Professor Penfield has carefully determined, not only the fluorine, but also the water yielded in the course of analysis of specimens from different localities, and finds that the analytical results are best explained by the hypothesis of an isomorphous replacement of fluorine by hydroxyl; further, he discovers that the magnitude of the angle between the optic axes is a function of the amount of that replacement.

The successes achieved in the artificial formation of minerals, the advances made in the methods of discrimination of minerals by the blowpipe and micro-chemical reactions, the increase in our knowledge of the modes of alteration of minerals, of their association, of their modes of occurrence, must all be left undiscussed.

Instruments.—I may add a word relative to the instrumental appliances which have been placed at the service of the mineralogist since the issue of Whewell's Report. As regards goniometers, the provision of two mechanical circular movements in perpendicular planes for the easier adjustment of a crystal-edge parallel to the axis of the instrument, first suggested by Viktor von Lang when assistant at the British Museum, has proved a great convenience and is now in general use. The employment of a collimator with interchangeable signals, of a telescope with interchangeable eyepieces, and the provision of lenses and diaphragms for obtaining images from faces so small as to be invisible to the unassisted eye, would seem to have brought the reflective goniometer, the invention of our distinguished countryman Dr. Wollaston, to a degree of perfection where further improvement is scarcely to be looked for; though two crystallographers, Fedorow and Goldschmidt, have recently constructed instruments with an additional telescope and entirely different arrangements. It may be worthy of remark that, though reflective goniometers are generally made for use with very small specimens, one was constructed for the British Museum some years ago by which it is possible to measure the angles of a valuable crystal without removal of the specimen from a matrix of several pounds' weight.

The polariscope for use with convergent light, the stauroscope, the employment of polarised light with the microscope, the adaptation of the microscope for the observation of the interference-figures yielded by extremely minute crystals, the spectroscope in the investigation of selective absorption, have all proved of great service in the advancement of our knowledge of the characters of minerals.

Worthy of special mention is that recent addition to our resources, the total reflectometer, an instrument by which it is possible to determine with wonderful accuracy the refractive index or indices from observation of the reflected light. The process was long ago suggested by Wollaston; but it is only within the last few years that forms of instrument have been devised by Kohlrausch, Soret, Liebisch, Pulfrich, and Abbe, which make the method as precise in its results as that which depends on refraction by a prism. In its more refined forms the total reflectometer has been used to test the accuracy of the form of Fresnel's wave-surface: in the convenient, though less precise, form devised by Bertrand, the instrument is useful in the discrimination of the species of minerals.

For the measurement of the optic axal angle, when the angle is so large that the rays corresponding to the optic axes are totally reflected at the surface of the plate and do not emerge into air from the crystal, Professor W. G. Adams made the valuable suggestion that the crystal-plate should be interposed between two hemispheres of glass; several instruments on this principle have been constructed abroad, and have only been imperfectly satisfactory, but one lately made in this country for the British Museum, under the superintendence of my excellent colleague Mr. Miers, proves to be most efficient for the intended purpose. Mr. Tutton's apparatus for supplying monochromatic light of any desired wave-length is a noteworthy addition to the instrumental resources of the mineralogist. The meldometer of Joly for the more accurate determination of the fusing point of minerals should also be recalled to you.

In this slight sketch it has been possible to make only the barest mention of some of the more important results which have been arrived at since the issue of Whewell's Report. You will doubtless think that it must have been possible in the year 1832 to look forward enthusiastically to the progress which was about to be made. But though Professor Whewell was himself confident that valuable discoveries would reward the mineralogical worker, he was sadly depressed, and, I think I may venture to say, with good reason, by the neglect of mineralogical study in this country. His own words are: 'This decided check in the progress of the science has, I think, without question, very much damped the interest with which

Mineralogy, as a branch of Natural Philosophy, has been looked upon in England. Indeed, this feeling appears to have gone so far that all the general questions of the science excite with us scarcely any notice whatever. But a more forward and hopeful spirit appears to have prevailed for some time in other countries, especially Sweden, Germany, and more recently France.' Those are the words of despair of the future of British Mineralogy. I may add that in the same year he resigned his professorship of Mineralogy, and directed his vast energy to the advancement of other subjects; many of you will remember that he afterwards became Professor of Moral Philosophy and Master of Trinity College, Cambridge.

Now, I think that a country like our own, which aims at taking and maintaining a high place in the scale of civilisation, ought in some way or other to secure that in every important branch of learning there is a group of men in the country who will make it the main purpose of their lives to render themselves familiar with all that has been and is being discovered in the subject, will do whatever is possible to fill up the gaps in the science, and, last but not least, will make the more important results accessible to other workers for whom so complete and original a survey is impracticable.

No one will doubt that Mineralogy should be such an important branch of learning. Minerals existed before man was thrust upon the scene; they will possibly continue to exist long after he himself has passed away: at least as persistent as himself, they will have an interest for every age.

The Continental nations have not only long recognised the importance of mineralogical study, but have acted accordingly. The difference between action and inaction will be most clearly grasped if we compare the position of Mineralogy in Germany with that in this country.

In Freiberg, the centre of a mining district in Saxony, an institute was opened in the year 1766 for the scientific training of those students whose interest was in minerals, and the lectures on Mineralogy given there by Professor Werner became a prominent feature; of the many pupils of this remarkable man, Breithaupt, Von Buch, Haidinger, Humboldt, Mohs, Naumann, and Weiss may be especially mentioned as having afterwards distinguished themselves by their scientific work. Of other Germans, who have likewise gone to their rest after much labour given to the advancement of Mineralogy and Crystallography, men whose names will long be household words for mineralogists, we may especially recall Beer, Bischof, Blum, Credner, Hessel, Klaproth, Kobell, Lasaulx, Mitscherlich, Pfaff, Plattner, Plücker, Quenstedt, Vom Rath, Reusch, Gustav Rose, Heinrich Rose, Sadebeck, Scheerer, Sartorius von Waltershausen, Websky, and Wöhler. Of the many Germans who are now contributing to our knowledge of minerals it is an invidious task to make a selection, but we may mention Arzruni, Bauer, Beckenkamp, Bücking, Cathrein, Cohen, Goldschmidt, Groth, Haushofer, Hintze, Hirschwald, Klein, Klockmann, Knop, Laspeyres, Lehmann, Liebisch, Lüdecke, Mügge, Neumann, Osann, Rosenbusch, Sandberger, Streng, Voigt, Weisbach and Zirkel: most of them are University Professors of Mineralogy; all of them hold important positions as teachers of the subject. Further, the laboratories and instruments available for the teaching of practical work are in many cases, notably at Strassburg, Munich, Göttingen, and Berlin, of an elaborate character.

So much for Germany; let us now look at home. In the Universities of England, Wales, Scotland, and Ireland there is a grand total of—two Professorships of Mineralogy, one of them at Cambridge, the other, and younger one, at Oxford. Further, the stipends are nearly as low as they can be made; in the former case, according to the University Calendar, the stipend paid from the University Chest to the present holder of the office amounts to 300*l.* a year; in the more ancient but less extravagant University of Oxford, the Calendar states that the present professor receives, subject to previous deduction of income-tax, the annual sum of 100*l.*, and the necessary instruments and many of the specimens have presumably been provided from his private resources; in case of residence he is to be allowed another 150*l.* a year for the luxuries which University life involves. And these are the only teaching appointments in his own subject that a successful investigator of minerals can look forward to being a candidate for! The result is inevitable; all those students who intend to earn their own living, all those who feel anxious to undertake professorial work, conclude that, however much they may be interested in the investigation of the characters of minerals, they will do well to follow the example of Professor Whewell and turn to other branches of knowledge in which there is a more hopeful prospect of their studies meeting with practical recognition.

It cannot be expected that advanced Mineralogy will ever be able to command the attention of more than a limited number of students, seeing that its successful pursuit requires a preliminary knowledge of at least three other sciences—mathematics, physics, and chemistry—sciences which must be assigned a fundamental importance in any scheme of education; if a preliminary knowledge of geology can be added, so much the better. Only few students can find time in their undergraduate days to acquire a competent knowledge of these sciences and to proceed afterwards to the study of Mineralogy. But the comparatively flourishing condition of the science in Germany, France, and other countries indicates that this is not a sufficient reason for refraining from giving proper facilities and encouragement to those who wish to enter upon its study. Some years ago the University of Cambridge took a step in the right direction, and introduced Mineralogy into their examinational system in such a way that the students of Physics, Chemistry, and Geology can give time to the acquisition of a knowledge of Crystallography and Mineralogy, and obtain credit for that knowledge in the examination for a degree.

It is clear that if in the future there is to be an honourable rivalry between this and other countries in the advancement of the knowledge of minerals, each of our Universities should be enabled in some way or other to found Professorships of Mineralogy, and be prevailed upon to follow the example of Cambridge in encouraging the students of Physics, Chemistry, and Geology to acquire a knowledge of Crystallography and Mineralogy before their education is regarded as complete. Even where a student has no intention of devoting himself to advanced mineralogical study, an elementary knowledge of Crystallography and Mineralogy will be extremely useful in giving him a better grasp of his own special subject.

And if, perchance, any of you are anxious to reduce the amount of those unmentionable duties of which we have heard so much of late, and feel that you can best do this by the endowment of Professorships of Mineralogy in our Universities, I would advise you *not* to do what has been so long practicable at this Association, couple Mineralogy with any other science—that would be an unwise economy. Each of the sciences is now so vast in its extent that no professor can be thoroughly master of what has been done, and is now being done, by other workers, in more than one of them. I remember that in my younger days it was held by some at Oxford that the Professor of Mineralogy, a so-called subordinate subject, should continue to be paid on a lower scale than his brother professors, and that he should obtain a living wage by adding a college tutorship or a lectureship in some other subject to his professorial duties. It is not by the prospect of such appointments that you can expect the most capable men to be attracted to the study of minerals. The practical effect of such an arrangement would only be that a college lecturer would give formal teaching in Mineralogy while devoting his real energy to another subject in which the pupils are more numerous.

It only remains to thank you for the way in which you have listened to a technical address relative to a science for the study of which very few facilities have been offered to you in our own country. Not often does the mineralogist present himself before an audience; he sees only too clearly that

> The applause of listening senates to command,
> To read his history in a nation's eyes,
> His lot forbids;

but I shall not have broken the long silence in vain if I have made clear to you that, though the Science of Mineralogy is itself making great progress, we have hitherto given too little encouragement to its study in our own Universities, and lag far behind both Germany and France in the recognition of its importance.

The following Papers and Report were read:—

1. *Some Points of Special Interest in the Geology of the Neighbourhood of Oxford. By* Professor A. H. GREEN, *M.A., F.R.S.*

There are several spots around Oxford the names of which have come to be household words in the literature of geology.

It is not likely that I can add anything to what has been long known about localities which were favourite haunts of Buckland, Phillips, and other of our foremost geologists. But, as excursions to some of these places have been planned, I hoped it might be serviceable to recall attention to the more important of the specialities of these spots.

We hope to visit historic Stonesfield. Work will be begun at some brick- and ironstone-pits at Fawler, where the Liassic zones of *Ammonites capricornus*, *A. margaritatus*, and *A. spinatus* are well shown. Above these comes an attenuated representative of the Upper Lias, not more than 10 feet thick. The basement bed, with its mixture of ammonites elsewhere relegated to separate zones, which has been studied by Mr. Walford, is present. Above the Upper Lias we have the representative of the Inferior Oolite, here reduced to the two bands of

Chipping Norton Limestone.
Clypeus Grit.

The latter is referred to the Parkinsoni zone, the lower zones of the subformation being here absent.[1] On the hill above lie the workings in the Stonesfield Slate, with its mixture of terrestrial, fresh water, and marine forms, too well known to need special description. Quarries may afterwards be visited in Great Oolite (Upper Zone), Forest Marble, and Cornbrash, one of which shows a curious case of contemporaneous erosion.

An excursion over Shotover will show a succession from the Oxford Clay to the Neocomian Ironsands. One point of interest here is the little coral reefs of the Corallian Beds, and the bank of finely comminuted material, derived from their wear, which adjoins them.[2] The Portland Beds are sandy and shingly, and mark the margin of the southern Portlandian sea.

The Neocomian Ironsands are part of a long strip which runs from Wiltshire, through Oxfordshire and Bedfordshire, to Cambridgeshire and onwards. They are coarse, shingly, very current-bedded, obviously shore deposits. Possibly they were formed in a long strait that connected the northern and southern Neocomian basins. At most of the spots where they yield fossils, these are marine. But it is only natural that, as we go along a coast line where the physical conditions change from place to place, there should be a corresponding change in the character and fossils of the deposits. And it is so here. On a hill adjoining Shotover the Ironsands have long been known to contain fresh-water fossils. We are here facing what was the mouth of a river. At Faringdon, again, the beds depart widely from their normal type. There is no current bedding, indeed very little bedding at all. Their abundant fossils include sponges, most of which are very perfect, and delicate bryozoa but little worn, with scattered specimens of perfect brachiopods, all embedded in a matrix of very finely comminuted organisms. These facts seem to me to point to a tract of still water such as would be found in a sheltered bay. In the deeper water of the centre the fossils would be preserved entire, while over the shallow margins they would be ground small, and the finely comminuted matter swept into the central pit till it was filled up.

An interesting section occurs in a brick-pit near Culham. It shows—

3. Gault clay, with a band at the bottom containing sand, pebbles, and rolled fossils derived from the Neocomian Ironsands.
2. Thin band of earthy limestone; Kimmeridgian (?) or Portlandian.
1. Kimmeridge Clay.

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[1] Walford, *Q.J.G.S.*, xli. (1885), p. 38.

[2] Blake and Hudleston, *Q.J.G.S.*, xxxiii. (1877), pp. 308–311.

The Neocomian Ironsands are in full force hard by; at this spot they have been denuded before the Gault was deposited, and their ruins have accumulated towards the base of that subformation.

The Purbeck and Portland rocks of the Swindon outlier have been so often described that they need no special notice.[1] The shell-marks and tufaceous limestones of the Purbeck lie in a hollow worn out in the Portland rocks, and the two are most sharply marked off from each other. A limestone crowded with *Cerithium Portlandicum* marks the upper limit of the Portland. It has been irregularly denuded, and here and there small isolated blocks, which have escaped denudation, project up into the Purbeck. The Portlands have a shingly character in some beds, which must have been formed in shallow water.

2. *Report of the Committee for making new Sections in the Stonesfield Slate.*—See Reports, p. 304.

3. *On the Terraced Hill Slopes of North Oxfordshire.*
By Edwin A. Walford, *F.G.S.*

The green slopes of many of the minor vales of North Oxfordshire are scored with parallel terraces or terraced banks, frequently of such regularity in depth of step and slope as to present to the mind any other origin for their formation than that of the every-day work of natural forces. They have been described as camps, entrenchments, and amphitheatres, and those of other districts Mr. Gomme has described, and has cited the many theories of their origin.

Mr. Walford first drew attention to the Oxfordshire and Warwickshire terraced fields in 1886,[2] and dealt at greater length with the subject in 1890.[3]

He gives as causes of formation—

1. The downward creep of the surface and sub-surface soil.

2. The occurrence of the terraces upon one precise geologic line, the micaceous marls of the Middle Lias which come in below the Red Rock bed. The marls are porous and non-cohesive. On the slippery slopes the soil must creep. The rain and rain-wash loosen the light soil below and about the roots of the herbage and urge its movement downward. Terraces from an incipient stage, like an ordinary grass ridge, to minor and major terraced banks of varying regularity of form can be traced. Below these marls are depths of compact blue clay (the zone of *Ammonites margaritatus* if in near contact with the marls). A little below the point where the marls and clays meet is the line of water outflow. Along the line there is constant removal of marl by chemical and mechanical solution. The effect is the loosening and sliding of the land downwards and outwards. This movement is aided by the weight of the overlying mass of rock, sometimes twenty-five feet in thickness.

3. Free passage of water through the rock and marl is necessary, for the Upper Lias clays have, on the Oxfordshire terraced hills, either been wholly stripped from the hill top or pushed back by atmospheric denudation. Regularly terraced slopes are not found on clay-covered hills; the appearance of terraces is coincident with the wearing away of the clay 'roof.'

The amphitheatre form of terraced land is always a valley head. The outflow of the stream—the valley-maker—marks ordinarily the base of the amphitheatre. More frequently the terraces of the valley head are small in step and their curvature is broken. Such an instance is Kenhill, near Shennington. An instance of greater regularity of curvature and greater depth of step is the Beargarden, Banbury.

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[1] Blake, *Q.J.G.S.*, xxxvi. (1880), p. 203.

[2] E. A. Walford, *Edge Hill: the Battle and Battlefield*, p. 24. Banbury, 1886.

[3] E. A. Walford, 'On some Terraced Hill Slopes in the Midlands,' *Journ. Northampton Nat. Hist. Soc.*, January, 1890.

From the Edge Hill escarpment a fork of the Horton vale runs alongside Adsum Plantation, and makes what is known as Adsum Hollow. The terraces sweep in regular curves along the high banks of the stream, and where it joins the main vale to the North of Horley the steps are so prominent as to give the name of Steps Meadow to the ground. Gredenton Hill, on the Burton Darrett range, is very regularly and beautifully terraced on three sides.

The author does not attempt description of the chalk hills or the lynchets of Dorsetshire. The sandy marls of the Dorsetshire Inferior Oolite have a composition approaching that of the micaceous marls of the Midlands, and reasons like those brought forward will no doubt prove their similar mode of formation.

The Probable Range of the Coal-Measures under the Newer Rocks of Oxfordshire and the Adjoining Counties. By Professor BOYD DAWKINS, *F.R.S.*

The principle laid down by Godwin-Austen and Prestwich that the master or tectonic folds in the pre-Carboniferous and Carboniferous rocks are lines of weakness along which the newer rocks have been folded in later times, has been recently applied by Bertrand to the district of northern France. In the present communication the author proposes to see how far it can be used in the search after the buried coal-fields of the counties of Oxford, Buckingham, Berks, and Wilts.

From the relation existing between the tectonic anticlines and synclines in the districts of South Wales, Gloucester, and the West of England, where they can be studied at the surface in the Palæozoic rocks, most important conclusions may be drawn as to the coal-fields buried under the newer rocks in southern England. They are as follows:—

1. The Mid-Devon syncline, traceable eastwards until it cuts the sea-line near Bognor.

2. The North Devon anticline, which runs eastwards through the Vale of Wardour, past Salisbury, and along the anticline of the Weald from Petersfield to Dungeness.

3. The Mid-Somerset syncline, which sweeps eastwards through the Vale of Bridgewater and Glastonbury, through the chalk downs between Heytesbury and Hindon, to Haslemere. From this point it is continued to the east through Tunbridge Wells and Tenterden to the sea to the south of Hythe.

These three folds have no bearing on the range of the coal-fields in the drainage area of the Thames. The fourth, or Pembroke-Mendip anticline, and the fifth, or South Welsh syncline, are the two great tectonic folds which remain for consideration.

The Pembroke-Mendip anticlinal range, highly faulted and folded, is traceable westwards into South Ireland, and eastwards, through Pembroke and the peninsula of Gower, to the south of Cardiff, through Weston-super-Mare and the Mendip Hills. Throughout this area it forms the southern margin of the coal-fields. Near Frome it plunges beneath the Oolites. It is, however, clearly marked by the Upper Greensand anticline of the Vale of Pewsey, and by the Upper Greensand inliers of Ham and Kingsclere. Thence it passes along the line to the high downs past Basingstoke and Farnham to Peasemarsh, south of Guildford, where it is seen in an inlier of Weald clay. It is carried still further to the east by similar inliers south of Westerham, and at Wateringbury and Maidstone. From Maidstone it sweeps to the south-east, through Otham and Ashford, arriving at the coast close to Hythe. In the eastern portion of its course it has, in my opinion, been the chief factor causing the south-eastern trend of the North Downs in the district of Maidstone. It forms also the southern boundary of the South-eastern coal-field discovered in the boring at Dover, and of the coal-fields of northern France and Belgium.

The South Welsh syncline, only two miles wide at St. Bride's Bay, in the anthracite district of Pembroke, widens out into the coal-field of South Wales, twenty miles in width. As it approaches the upper estuary of the Severn it is represented by the outlying coal-field of the Forest of Dean, and the three partially or wholly covered fields to the north of the Mendip Hills, distributed through an area measuring forty-five miles from north to south. The wedge-like syncline, with its more or less connected coal-fields, continues to widen eastwards, its northern boundary being probably represented by a line drawn from the northern rim of the South Welsh coal-field to the north of the Forest of Dean, and continued due east beneath the Secondary and Tertiary rocks to some point between Walton-on-the-Naze and the mouth of the Blackwater. It passes through Gloucester, Rissington, in the valley of the Windrush, Blenheim, Kirtlington, Quainton, Luton, Bishop's Stortford, Dunmow, Braintree, and Colchester. The width of this great tectonic syncline between Colchester and Dover is about fifty miles, and it occupies nearly the whole of the London Tertiary basin, which, it must be noted, is of the same wedge shape, widening to the east.

The boring recently described by Mr. Whitaker at Culford, near Bury St. Edmunds, in which a slate rock, probably of Silurian or pre-Silurian age, was struck at a depth of 637 feet 6 inches from the surface, shows that in all probability that area is an anticlinal area. About forty-two miles to the south, in the deep boring at Harwich, the Yoredale shales come in. Both these points are, be it remarked, to the north of the line in question. Both indicate a Palæozoic area in Suffolk and northern Essex older than the Coal-Measures, and similar to that on the same meridian in South Wales and Gloucestershire which lies to the north of the western coal-fields. We have, therefore, not merely a well-defined Pembroke-Mendip anticline forming the southern boundary of the coal-fields both in the west and in the east, as proved by the south-eastern coal-field at Dover, but also evidence of the continuation of the South Welsh pre-Carboniferous barrier of Hull, which forms the northern boundary of the visible coal-fields due eastwards into Suffolk. It may therefore be reasonably inferred that similar coal-fields, isolated from each other by tracts of older rocks, are to be found in the South Welsh syncline where it lies buried beneath the Secondary and Tertiary strata. In other words, we may conclude that there are coal-fields in North Wilts, in the counties of Berks, Oxford, and Buckingham, and the Tertiary basin of the Thames within the limits laid down above, and in a direction indicated in 1871 by the Coal Commissioners.

One such coal-field, indeed, has already been discovered in a deep boring at Burford, near Whitney, in the valley of the Windrush. The discovery, however, has unfortunately not been followed up, and we do not know whether it is of wide east and west range, similar to that of South Wales, or of Bethune and Namur, or whether it is small and unimportant, like some of the smaller coal-basins north of the Mendip Hills. It offers a sure basis for other deep borings, which may have the same industrial effect on Oxfordshire as those which have extended the range of the buried Coal-Measures in northern France, ninety miles to the west of Charleroi, and converted a purely agricultural into a great manufacturing district. There is no practical difficulty arising from the depth at which the Coal-Measures may be expected to occur in this region. At Burford they were struck at 1,184 feet from the surface, and at Dover at 1,113 feet below high-water mark.

The borings in the area of the London Tertiaries prove that the Palæozoic rocks are not buried to a greater depth than about 1,200 feet below sea-level, and in Hertfordshire to as little as 796 feet. The most important collieries in England are carried on at depths ranging from 1,500 to more than 3,000 feet.

The new light thrown upon the question of the buried coal-fields by recent discoveries places it in a very different position from that which it occupied in 1871, when Godwin-Austen, Prestwich, and Hull gave their evidence before the Royal Commission. The boring at Dover, revealing the existence of a valuable coal-field, now offers a fixed point for further discovery in south-eastern England. That at Burford offers a similar basis for the proving of the Oxfordshire coal-field. The many other wells and borings made in the area of London, and as far north as Bury St. Edmunds, also afford important information as to the northern boundary of the productive South Welsh syncline. The development of our mineral wealth is of such vast importance that it would be quite worth the while of the Government to undertake a series of experimental borings, which would indicate the exact position of the buried coal-fields. In the present state of the mining laws it is a task not likely to be undertaken by the private adventurer. It might, however, be carried out by the County Councils, or by a combination of landowners, either with or without a compulsory rate, on the property which would be benefited by the discovery of new fields. It is one of those objects of public utility which are especially worthy of the regard of the British Association at this time and in this place.

5. *On the Deposit of Iron Ore in the Boring at Shakespeare Cliff, Dover.*

By Professor BOYD DAWKINS, *F.R.S.*

The general results of the boring at Dover were laid before the British Association at Cardiff in 1892, so far as relates to the discovery of the south-eastern coal-field. In the present communication the author treats of a bed of ironstone, which is likely to be of great importance in the new industries which will spring up sooner or later in Kent in consequence of the discovery of coal in workable quantities.

The strata penetrated in the boring are as follows:—

		Feet
Upper Cretaceous	Lower Grey Chalk and Chalk marl	130
	Glauconitic marl	8
	Gault	121
Neocomian	Folkestone Beds	64
	Sandgate Beds	77
	Hythe Beds	87
	Atherfield Clays	18
Oolitic	Portlandian	32
	Kimmeridgian	73
	Corallian	159
	Oxfordian Callovian	188
	Bathonian	156
	Total	1,113
Coal-measures with twelve seams of coal 23 feet 5 inches thick		1,068½

The ironstone occurs in the Kimmeridgian part of the section, and as shown in the following details:—

Portlandian Beds:—	Feet
Grey marl with oolitic grains of ferric oxide	2
Hard grey limestone	1
Brown calcareous sandstone	2
Grey shelly limestone with oolitic grains of ferric oxide	1
Dark-grey marl	2
Hard blue limestone with Littorina	1
Brown oolitic ironstone	12
Grey limestone	4
Dark bituminous clay	8
Flaggy sandstone	2
Grey sandy clay	4
Arenaceous limestone with Cidaris	7
Dark bituminous shale	27
Grey nodular limestone	2
Coralline Oolite with the usual fossils, *Pecten vagans*, &c.	27

The ironstone presents very singular physical characters. It is composed of small dark-brown shining grains of hydrated oxide of iron like millet seed, embedded in a crystalline base partly of calcium carbonate, and partly of iron carbonate. These grains are oolitic in structure, and are probably the result of the same chemical change by which the calcareous beds of the Inferior Oolite in Lincolnshire have been converted into the iron ores. They occur, it will be noted, in several strata above the main bed, 12 feet in thickness in the above section.

This bed of iron ore is identical with that described by Blake and Hudleston at Abbotsbury in Dorset, where it occurs between the Kimmeridge clay above and the Corallian rocks below.

It is also physically identical with the valuable iron ore worked for many years at Westbury in Wiltshire, where it is met with at a lower horizon, being there separated from the Corallian limestones by 4 feet of marls and sands.

This stratum, although probably of purely local origin, is to be looked for in the beds above the Corallian throughout the whole of southern England, from Dorset eastwards. Its discovery at Dover is only second in importance to that of the South-eastern Coal-field. It will have to be taken into account in the future development of the coal-fields in southern England.

6. *On the Cause of Earthquakes. By* J. LOGAN LOBLEY, *F.G.S., Professor of Physiography, City of London College.*

Although a connection between the cause of volcanic and of seismic action is generally assumed, neither has been satisfactorily determined, though both are usually attributed in their inception to a shrinkage of the globe from secular cooling. The author took exception to this view, and adduced the great amount of rock-folding since the Cambrian Period, as showing that if this were due to planetary shrinkage, which rock-folding is assumed to prove, the earth's radial contraction must have been at least 100 miles during post-Cambrian ages, that such a contraction would require a loss of heat to the extent of 5,000° F., that therefore the globe would have had at the Cambrian Period a temperature 5,000° F. higher than at present, and that such a temperature was altogether incompatible with terrestrial conditions. Neither, apart from greater terrestrial heat, would meteorological conditions be at all like the present, with a surface 100 miles further from the centre, for an attenuated atmosphere and different gravities would affect all climatal conditions and all the agencies of nature.

Both the petrological and the palæontological teachings of the Cambrian rocks are entirely at variance with any such conditions, since they indicate terrestrial inorganic conditions and agencies similar to those of the present epoch.

It was submitted, therefore, that the assumption of a planetary shrinkage was opposed to geological facts, and that consequently another cause must be sought for seismic phenomena.

The author thought the hypothesis he brought before the Section in 1888 to account for volcanic action[1] would meet the difficulty, and expressed the opinion that earthquakes were originated by chemical action arising from favouring physical conditions at separate and isolated dynamic foci, at moderate depths and quite unconnected with any central fused mass. These originating foci, like those of both volcanic and plutonic action, were in a thin outer rind of the globe of a few miles in thickness, which with all its foldings and plications rested upon a solid foundation, giving the earth its ascertained rigidity, and since the Cambrian Period there has been no appreciable decrease of the bulk of the globe or of terrestrial heat.

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[1] 'On the Causes of Volcanic Action,' *Report of the British Association for* 1888 (Bath Meeting), p. 670.

7. *On Certain Volcanic Subsidences in the North of Iceland.*

By TEMPEST ANDERSON, *M.D.*, *B.Sc.*, *F.G.S.*

Perhaps the most striking features in Icelandic scenery are the *giás* (pronounced 'geow'), or fissures and chasms which are so frequently met with in all the districts in which recent volcanic activity manifests itself. They are usually, and in most cases rightly, ascribed to the lower stratum of a molten lava stream having obtained an outlet after the surface has consolidated into a crust of greater or less thickness.

Giás of this class are, so far as the author has been able to observe, confined within the limits of a single lava stream, and do not affect previously formed rocks. Usually there is a large giá roughly parallel with each side of the original lava stream, and the space between these has subsided considerably. Any giás in this subsided portion are much smaller, and obviously of secondary importance. Examples of this are to be found in the well-known Almanagiá, at Thingvalla, which has a throw of about 100 feet, while the sides of the smaller giás which enclose the Logberg in the subsided portion are practically on the same level.

There are also several such subsidences near Lón and Ásbergi, in the North of Iceland. The main subsidence at Ásbergi is a little more complicated, though evidently due to the same causes. Here a large roughly triangular area has subsided, the throw at the apex being probably nearly 300 feet, but a space in the middle has remained at its original height, so that a depression has been produced like a great V, the portions both between and outside the legs having remained standing. In the case of Thingvalla it appears not unlikely that the lava which flowed down into the lake solidified on coming in contact with the water and formed a wall sufficiently strong to hold up the lava plain till it formed a firm crust, and that the giving way of this and the escape of the molten lower layers into the deeper parts of the lake caused the subsidence.

Similarly the lava which escaped from Ásbergi may have been that which now occupies the low ground near the estuary of the Jokulsá, in the direction of Lón.

On the east and south-east of Lake Myvatn a very extensive eruption, or series of eruptions, has taken place from a chain of craters locally called Gardr Borgir ('the castles of Gardr,' which is the name of a farm). The lava flow has occupied nearly all the bed of Lake Myvatn, and flowed down the valley of the Laxá to its mouth at Laxamyri. All this stream of lava is very remarkable for the number and size of the spiracles with which it is studded, and a regular gradation of sizes exists, between spiracles the size of a haycock and cones some of which cannot be less than 200 feet high. These cones and craters, which constitute such a striking feature of Lake Myvatn, may probably be nothing more than spiracles formed by the escape of steam generated by the conflict of the hot lava with the water of the lake. The barrier which holds up the water of the present lake consists of this lava, and caves exist in it which are obviously channels by which molten lava has escaped. These and deeper-seated ones would be those by which the lava escaped and left the depression occupied by the present lake. Between the craters of eruption and the lake no spiracles were noticed, but there is a very remarkable series of rocks—the Dimmuborgir—masses of lava of fantastic shape, 30 or 40 feet high, which have remained standing while the intervening portions have subsided. They present slickenside marks where the subsiding portions have scratched the masses that have remained standing, and tide-marks where the crust has halted in its descent; also in many places bulgings, where the lava has been scarcely stiff enough to stand, and others where it has actually formed stalactitic masses.

So far for actual lava subsidences.

The special object of this paper is to draw attention to a subsidence on the slopes of Leirnukr, a volcano several miles north of Myvatn, where a large strip of land, perhaps 200 yards wide and one mile or more long, has been let down to a varying depth, averaging perhaps 60 to 80 feet.

The faults bounding it, like nearly all the fissures in this district, run north and south; and the east face, which is most perfect, cuts right through a thick stream of old columnar lava and through a large boss of tuff, round and over which the lava has bedded itself, and also through the tuff rocks at each side of the lava stream. It would appear worthy of consideration whether this great depression, which thus affects all the crust of the volcano impartially, may not have been caused by the falling in of one of the steam cavities which may be presumed to exist under volcanoes after the lavas ~~have been~~ expelled by the steam pressure.

This would accord with the observation that sedimentary rocks near volcanoes often dip towards those volcanoes. Mr. Goodchild has informed the author that the sedimentary rocks round Arthur's Seat are much thicker the nearer they are to that old volcano, as if the ground had slowly sunk while they were being deposited.

Near Lón the author was shown a small gjá, said to have been formed during an earthquake in February 1885. The crack was of a freshness corresponding to such a date, and was only a few inches wide, and so short that it could not be determined whether it extended beyond one bed of lava. It certainly was not an example of the escape of liquid lava from below a crust, nor of a subsidence over a steam cavity, and its chief interest in this connection is as showing that at least three separate sets of causes are at work in producing the gjás of Iceland.

FRIDAY, AUGUST 10.

1. A joint discussion with Section H on the Plateau Gravels, &c., West Kent, was opened by the following two communications:—

(a) *On the Geology of the Plateau Implements in Kent.*[1]

By Professor T. Rupert Jones, *F.R.S.*, *F.G.S.*

This subject having been fully treated of by Professor Dr. Prestwich, the requisite references to his various memoirs elucidating the general geology of the local drift-deposits, the geological stages of their formation, and the peculiar flint implements of the plateau were given. He has shown that certain superficial soils on the North Downs between Sevenoaks and Rochester contain numerous rudely worked flints, discovered by Mr. B. Harrison; and that these were derived from a gravel, of very great antiquity, originally formed on the side of the old Wealden Hill-range or Mountain, which once rose about 3,000 feet above where Crowborough and other hills in Sussex now are. Man existed at the time of these gravels, and used the flints for tools. These gravels and the implements left in them were removed by natural agencies, such as rain, rivers, sea, frost, snow, and ice, and distributed by torrential streams on the Chalk slopes (now part of the North Downs) at a lower level on the flanks of the range.

These rude old flint implements have an ochreous colouring, due to ferruginous gravel whence they came; and are now found on the plateau, sometimes with limited patches of some of the ochreous flint gravel, together with Tertiary pebbles, less-worn flints, and fragments of Lower Greensand, on the red 'clay-with-flints' covering the Chalk. It was shown how desirable systematic excavations, to prove the extent and thickness of the implementiferous soil, would be.

Professor Prestwich's history of the origin of the ancient Wealden Dome, Island, and Hill-ranges, and of the gradual destruction of those uplands, in the course of untold ages, with the resulting formation and removal of successive geological groups of strata, such as the Thanet Sands, Woolwich-and-Reading Beds, London Clay, Lenham Beds, and the old ferruginous gravel with its rude implements above mentioned, was noticed in detail.

The Diestian or Lenham Beds were formed in the Early Pliocene period; and the denudation of Holmesdale probably began directly afterwards, at about the time of the Red or the Chillesford Crag in Late Pliocene, or in Post-Pliocene times; and the old ferruginous gravel had not only been formed, but washed away to a lower level before that time.

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[1] This paper has been printed in full in *Natural Science*, October 1894.

The ultimate denudation of the valleys cutting off the Chalk from the Weald being subsequent to the formation and removal of that gravel, the latter must have been Pre-glacial in age.

(b) *On the Age of the Plateau Beds.* *By* W. WHITAKER, *F.R.S.*, *F.G.S.*

Mr. Whitaker said that the flints exhibited might be divided into two classes, the few that would be allowed by every qualified observer to be the work of man and the many as to the authenticity of which judgment should be deferred. He then alluded to the two points of view from which the subject was approached, the anthropological and the geological. In the former the work of man was the starting point; but, as a geologist, he thought that Nature should be duly considered, and the varied way in which she worked, sometimes leading to results that were somewhat unexpected. The district in question, too, was of a double character. In the first place, we had to do with a tract, south of the Chalk range, over which there were in parts beds of gravel, sometimes along the courses of the stream-valleys, but sometimes having no connection with the present drainage-system. In the latter case the composition and position of the gravel seemed to point to a time when the features of the country were not the same as now, when the streams ran in different courses, and when the Chalk escarpment and other similar ranges of hill reached further south than now. He pointed out that the district was at and near the watershed between the Medway and the Darent, and that in such a position alterations in the flow of streams could be brought about by smaller causes than lower down along the river-valleys. The other part of the district was along and north of the great Chalk range, and the deposit here mostly met with over the Chalk could not properly be called Drift; it had not been brought into its present position from elsewhere by sea, river, or ice, but had grown where it stood; it was a residuum, the matter left from long-continued gradual dissolution of the chalk and the leaving behind of its flints and other insoluble matter, to which was added a mass of loam, resulting presumably from the remains of old Tertiary beds. With regard to the gravels, flint implements of undoubted workmanship having been found in them, it must be conceded that man existed at the time of the deposition of those gravels. This certainly carried man back, locally at all events, beyond the time of the river gravels, which occur in the bottoms and along the slopes of the valleys. He could not admit, however, that there was any good evidence to connect these ancient men with Pre-glacial or even with Glacial times, as there were no deposits of undoubted Glacial age in or near the district. Over the Clay-with-flints of the Chalk tract many implements had been found, but these were on the surface, and therefore we had no evidence of their age other than that given by their form. He understood that it had been said that a very few implements had been found in the Clay; but even were it so we should be little wiser as to their age, the formation of this clay having continued over a long time, right down to the present day. Elsewhere implements had been found in a brickearth that was associated with the Clay-with-flints; but in this case we were still ignorant of the age of the deposit, no other bed having been found above. He thought that in such a matter great caution was needed lest observers should be carried away by their zeal in discovery, and that the right spirit was to approach the question with wholesome doubt, contesting the views of those whose faith led them to believe very ordinary-looking chippings to be the work of design, so that they should have to prove that the balance of probabilities was in favour of their view.

The following Papers and Report were read:—

2. *On the Traces of Two Rivers belonging to Tertiary Time in the Inner Hebrides.* *By* Sir ARCHIBALD GEIKIE, *F.R.S.*

Many years ago the author had described part of the course of a stream which had cut its channel in the lava-plateau of the Isle of Eigg, and, as shown by the materials of its gravel deposits, had flowed from east to west. The channel of the main river, as well as those of some of its tributaries, had been sealed up under a flow of pitchstone, which, after ages of waste, now forms, owing to its greater durability, the prominent ridge of the Scuir, the original higher ground of bedded basalt having been worn down into lower slopes. The river-course thus entombed must be assigned to the volcanic period of older Tertiary time in this country. Its western end is truncated by a precipitous sea-cliff, at the top of which a section of it is displayed, with its underlying shingle and overlying pitchstone, at a height of some 500 feet above the sea. This summer the author had enjoyed a favourable opportunity of visiting Hysgeir, a small low islet about eighteen miles to the west of Eigg, which had recently been identified by Professor Heddle as a continuation of the rock of the Scuir. He was able completely to corroborate this identification. The pitchstone of Hysgeir in its external forms and internal structure precisely resembles that of Eigg, presenting, indeed, so close a resemblance that it looks like a detached piece of the high ridge of the Scuir. Unfortunately, the columnar rock everywhere slips under the sea, and allows no trace to be seen of what it rests upon. If it be approximately as thick as it is in Eigg, its base may be 200 or 300 feet below sea-level. The gradual fall of the river-bed from east to west had been noticed at the Scuir, and the position of the pitchstone at Hysgeir showed a continued declivity in the same direction of perhaps as much as 35 feet in the mile. No visible rock rises to the surface of the sea between Hysgeir and Eigg. The region has been intensely glaciated, and the low ridge and rocky slopes of Hysgeir are strewn with erratics, which show that the ice moved westwards from the Inverness-shire highlands.

A much older river, but one still belonging to the volcanic period, has left some interesting records in the islands lying to the north of Hysgeir. A succession of coarse river-gravels are there found intercalated on different horizons among the bedded basalts. The materials of the lowest of these conglomerates are remarkably coarse, blocks 6 feet in length being occasionally visible. They consist in large measure of volcanic rocks, especially slaggy and amygdaloidal varieties. These constitute the largest and least water-worn blocks. Pieces of Torridon sandstone, epidotic grit, quartzite, and various granites and schists are generally well-rounded and smooth, and especially abound in the finer and more stratified gravels. The rapid dying out of thick sheets of coarse conglomerate is a conspicuous feature of the deposits, their place being sometimes taken by layers of fine tuff or volcanic mudstone, or by shales with remains of land-plants. Some portions of the conglomerate pass into true volcanic agglomerate, and this latter rock can in one place be seen to rise as a neck enclosing blocks of scoriæ and basalt sometimes 15 feet in length.

The sequence of events which these various deposits indicate appears to be as follows. During the outpouring of the lavas of the great basaltic plateaux of the Inner Hebrides a river flowed across the volcanic plain from the Western Highlands, whence it carried large quantities of shingle. By successive violent floods these materials, together with the detritus of the lava-fields, were strewn irregularly far and wide beyond the immediate channel of the river. In the pools left behind, fine volcanic silt gathered and entombed leaves and stems of the surrounding terrestrial vegetation. But volcanic activity still continued, and, though cones of slags and pumice were swept down, new eruptions took place by which masses of rock, sometimes 9 feet in diameter, were thrown out to a distance of a mile or more, and fresh streams of lava were poured out, completely burying the previous accumulations. Renewed river-floods of gradually lessening severity spread fine detritus over the cooled sheets of basalt, and again these later fluviatile deposits were entombed beneath fresh outbursts of lava. Perhaps no more striking evidence can be elsewhere obtained of the conditions of the land-surface over which, from many scattered vents, the materials of the volcanic plateaux of the Inner Hebrides were slowly piled up.

3. *On a New Method of Measuring Crystals, and its Application to the Measurement of the Octahedron Angle of Potash Alum and Ammonia Alum.* *By* H. A. Miers, *M.A., F.G.S.*

The two fundamental laws of crystallography—namely, (1) the constancy of the angle in crystals of the same substance, and (2) the law of simple rational indices—seem to be violated by those crystals which are liable to irregular variations in their angles, or those which have the simple faces replaced by complicated 'vicinal' planes.

Both these anomalies are exhibited by potash and ammonia alum. Brilliant and apparently perfect octahedra of these salts show large variations in the octahedron angle; other crystals show low vicinal planes in place of the octahedron faces.

If it be true, as is supposed, that the octahedron angle varies in different crystals, it would be interesting to ascertain whether progressive variations can be traced during the growth of a single crystal, and whether some or all of the octahedron faces change their direction in space if the crystal be held fixed during growth.

In order to solve this problem a new goniometer has been constructed, in which the crystal is fixed at the lower end of a vertical axis, so that it can be immersed in a liquid during measurement.

This device is in reality an inversion of the ordinary goniometer with horizontal disc; the liquid is contained in a rectangular glass trough with parallel-plate sides; one side is placed rigidly perpendicular to the fixed collimator, and the other is perpendicular to the telescope, which is set at 90° to the collimator. The trough is supported on a table which can be raised and lowered, so that the crystal can be placed at any required depth in the liquid. If the liquid used be its own concentrated solution the crystal can be measured during growth, and the changes of angle, if any, can be observed at different stages.

In order that it may be held rigidly, the crystal is mounted, when small, in a platinum clip, which it envelops as it grows larger.

The results derived from the measurement of a large number of alum crystals are as follow:—

(1) The faces of the regular octahedron are never developed upon alum growing from aqueous solution.

(2) The reflecting planes (which are often very perfect) are those of a very flat triangular pyramid (triakis octahedron) which overlies each octahedron face.

(3) The three faces of this triangular pyramid may be very unequal in size.

(4) The triakis octahedron which replaces one octahedron face may be different from that which replaces another octahedron face upon the same crystal.

(5) During the growth of the crystal the reflecting planes change their mutual inclinations; the triakis octahedron becomes in general more acute, *i.e.*, deviates further from the octahedron which it replaces, as the crystal grows.

(6) This change takes place not continuously, but *per saltum*, each reflecting plane becoming replaced by another which is inclined at a small angle (generally about three minutes) to it.

(7) During growth the faces are always those of triakis octahedra; if, owing to rise of temperature, re-solution begins to take place, faces of icositetrahedra are developed.

Conclusions.

The above observations prove that the growth of an alum crystal expresses an ever-changing condition of equilibrium between the crystal and the mother liquor. It does not take place by the deposition of parallel plane layers; new faces are constantly developed: since these succeed one another *per saltum* they doubtless obey the law of rational indices, though not that of *simple* rational indices.

From the mutual inclinations of ~~these vicinal~~ faces it is possible to calculate with absolute accuracy the angle of the faces to which they symmetrically approximate. This angle is found to be that of the regular octahedron, 70° 31¾′. The octahedron angle of alum is not, therefore, as appeared from the observations of Pfaff and Brauns, subject to any variation.

The angle at which a given vicinal plane is inclined to the octahedron face is independent of the area of the plane, and of the temperature of the solution and of the barometric pressure: it appears to be conditioned by the concentration of the solution at the surface of the plane.

In confirmation of this view it is found that the upper and lower portions of an octahedron face which stands vertical are often replaced by two different triangular pyramids; also that the three faces of one such pyramid are at a given moment not necessarily equally inclined to the octahedron face which it replaces.

When, as is often the case, one of the three vicinal planes is large and the other two are too small to give a visible reflexion, the face appears to be a single reflecting plane. It is this which has been mistaken for the octahedron face in previous observations.

Similar phenomena of growth are exhibited by crystals of other substances belonging to different systems. The conditions of equilibrium between the crystal and the solution are such that vicinal planes appear in place of simple forms; these vary with the concentration of the solution, and give rise to variations in the measured angles which are only apparently anomalous. Their true position can be determined on a crystal of cubic symmetry (such as alum) whose theoretical angles are known.

A further study of the faces developed during the growth of crystals will, it is hoped, lead to a better understanding of the reasons why a simple face like the octahedron should not be a surface of equilibrium, and of the relation between the vicinal planes and the structure of the crystal.

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4. *A Comparison of the Pebbles in the Trias of Budleigh Salterton and of Cannock Chase. By* Professor T. G. BONNEY, *D.Sc., LL.D., F.R.S.*

The pebbles in the two deposits correspond in certain respects. In both vein quartz and various quartzites are abundant, with certain dark green rocks, which undoubtedly in some, probably in most, cases owe their colour to minute tourmaline. The compact quartzites so common in Staffordshire are found in the Devonshire deposit, but less abundantly, while other quartzites more rare in the former are commoner in the latter. A quartz-felspar grit like the Torridon Sandstone occurs in both. The following are points of difference. The shape of the Staffordshire pebbles is nearer to a prolate spheroid, that of the Devonshire to an oblate one: igneous rocks are much rarer in the latter, and the compact tourmaline rocks in the former. The author thinks that the pebbles at Budleigh Salterton must have travelled from a more or less south-westerly quarter, and that the frequent correspondence of materials indicates that somewhat similar detrital rocks fringed the archæan rocks of the ancient western land in localities far apart.

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5. *On a Soda-Felspar Rock at Dinas Head, North Coast of Cornwall. By* HOWARD FOX.

Dinas Head adjoins Trevose Head, four miles west of Padstow.

The base and foreshore of the headland appear to be entirely composed of greenstone containing much calcite, probably an altered dolerite.

Between the greenstone and the slate, as well as interbedded with the slate, occurs a rock which covers about an acre. It assumes various characters, all of which contain nearly 10 per cent. of soda and from 64·4 to 66·6 of silica. The compact varieties are crypto-crystalline, and might easily be mistaken for cherts. The concretionary and spherulitic varieties show grains and blades of a felspar which is doubtless albite. It varies in colour from creamy grey to light brown and dark bluish-grey; it weathers white, and is often studded with cavities filled with rusty brown material containing crystallised quartz. This rusty-coloured material occasionally weathers out as nodules 8–10 mm. in diameter, projecting 10–15 mm. beyond the white surface of the rock. In other places this rock contains lenticles and concretions of calcareous matter of considerable size, with concentric structures around some of them. When interbedded with slate it is densely studded with small rusty brown spots, sometimes irregular and sometimes of such forms as would be yielded by rhombs; they are undoubtedly pseudomorphs after carbonate. It has in places all the appearance of a stratified rock, and is distinctly bedded. In one locality this rock assumes a nodular form, with the outer edges composed of spherulites varying from 2 to 10 mm. in diameter. The central portions of the spherules are composed of crypto-crystalline material, the outer portions of radiating blades or prisms of felspar, presumably albite. Ferric oxide is scattered through the rock in irregular patches, in veins, or in radial streaks between the blades of felspar, or occasionally it is almost wholly concentrated in the polygonal sutures formed by the mutual interference of adjacent spherulites.

The greenstone is posterior to and intrusive in this soda rock, and cuts across, bends, and disorders its beds. Extreme crushing has in places altered the original junction line, and thrust planes and fault breccias are seen. Quartz veins traverse both rocks, but are more numerous in the soda rock.

The slate is interbedded on the northern side of the headland with bands of blue limestone, and is occasionally studded with ferruginous patches and nodules in much the same way as the soda rock.

A rock containing as much as 7·54 per cent of soda is said by Kayser to occur as a contact product due to greenstone in the Hartz. The question arises, Is this Dinas Head rock an adinole or a soda felsite—*i.e.*, a keratophyre? The presence of ferriferous carbonates favours the theory of its being an altered sedimentary rock, whilst the spherulitic and concretionary structure favours the theory of its being an igneous rock.

6. *Report of the Committee on Geological Photographs.* See Reports, p. 274.

SATURDAY, AUGUST 11.

The following Reports and Papers were read:—

1. *Report of the Committee on Palæozoic Phyllopoda.*—See Reports, p. 271.

2. *Report of the Committee on the Eurypterid-bearing Deposits of the Pentland Hills.*—See Reports, p. 302.

3. *Preliminary Note on a New Fossil Fish from the Upper Old Red Sandstone of Elginshire. By* R. H. TRAQUAIR, *M.D.*, *F.R.S.*

These remains consisted of large broad thick plates gently hollowed in boat-like fashion, and showing no articular surfaces along any of their free margins. None of these plates had been found entire, though pieces had occurred of over a foot in length and a quarter of an inch in thickness. To these plates the author has given the name of *Megalaspis Taylori.*

4. *On the Homes and Migrations of the Earliest Forms of Animal Life as indicated by Recent Researches.* By HENRY HICKS, *M.D.*, *F.R.S.*, *F.G.S.*

The author, after giving a history of the finding of zones of animal life at lower and lower horizons in the Cambrian rocks during the past forty years, referred to some recent evidence which points to the extension of similar forms of life over very large areas. That there were many centres of dispersion in different parts of the world seems certain; but as the migrations of the forms found on each side of the Atlantic seem to have taken place contemporaneously, the author believes that the original home of these forms must have been at some point in the Atlantic when that basin was much narrower than it is at present. The author then referred to the evidence, showing a gradual development in these earlier forms of life, and to some points bearing on the question of evolution.

5. *On some Vertebrate Remains from the Rhætic Strata of Britain. (Third Contribution.)* By MONTAGU BROWNE, *F.G.S.*, *F.Z.S.*

LABYRINTHODONTIA.

Parts of jaws and teeth of a Labyrinthodont Amphibian are found commonly, though very imperfect, in the 'bone-bed' of Aust Cliff, Gloucestershire. So much material has been accumulated that it may be as well to record that ten specimens of the pre-maxilla—showing large 'tusks' and a serial outer row of smaller teeth—are known to the writer, four of which are in the Bristol Museum, where they are labelled 'Jaws of Enaliosaurians,' and six others, from Aust and Westbury-on-Severn, are in his own possession. One of these was sent as the 'scute of a reptile;' and another, before its development from the matrix, was so much like a coprolite as to lead to the inference that others may have been previously passed over. Of the maxilla there are six large portions and several smaller ones, carrying both large and small teeth of two distinct characters. Several large and many small pieces represent the mandible, some, near the symphysis, showing large teeth. Of teeth, both seated upon the bone and broken away, there are a great many examples of all sizes. Five pieces are apparently portions of the palato-vomerine element, carrying large and small teeth.

Between fifty and sixty specimens are fragments of the jaws, and there are many specimens which are doubtless portions of the elements of the skull and of the thoracic plates. A few portions of limb-bones are doubtfully referable to the Labyrinthodontia.

The definite determination of the pre-maxilla, portions of the maxilla, mandible, and some other parts of the Labyrinthodontia, appears to be a new record for the Rhætic of Britain. No speculation is hazarded as yet as to the generic or specific determination of these remains, as if not referable to *Metoposaurus* (*Metopias*) *diagnosticus*,[1] they appear to have affinities with *Trematosaurus* in the character of the united or single pre-maxilla, and by the large tusks being internal to the serial mandibular teeth; on the other hand, the anterior or 'tusk' teeth are large—some of them ¾ in. in diameter—each with a correspondingly large pulp-cavity, and although apparently simply plicated in the exserted portion, yet at the extreme base the plications of the dentine are complex, and somewhat resemble those shown in the teeth of *Mastodonsaurus Jägeri* as figured by Meyer.[2]

The presence of teeth of two characters—large or Labyrinthodont, and small or 'Saurichthyan'—in the same jaws, together with the characters of the external surface and alveolar palatal extension of the maxilla and of sections thereof, leads to the conclusion, hinted at in the last Report under the heading of *Termatosaurus crocodilinus*,[3] that '*Saurichthys*' is a non-existent piscine genus, and that jaws figured under that heading are mainly referable to those of Labyrinthodonts, and that teeth of '*Saurichthys*' of various authors can be definitely assigned—

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[1] Miall, *Rep. Brit. Assoc.*, 1874, p. 157; but see Lydekker, *Cat. Foss. Rep. and Amph.*, p. 157.

[2] *Die Saurier des Muschelkalkes* (1847–55), Tab. 64, fig. 2.

[3] Montagu Browne, *Rep. Brit. Assoc.*, 1893, p. 749.

1. To Labyrinthodontia, sp.
2. To *Plesiosaurus rostratus*.
3. To *Hybodus*, sp. (symphysial teeth).
4. To *Gyrolepis*, sp., and perhaps *Colobodus*, sp.

'RYSOSTEUS.'[1]

This genus was instituted by Owen from the examination of a single anterior dorsal vertebra 'half imbedded in its pyritic matrix from the bone-bed of Aust Passage, near Bristol,' and of other portions from Westbury-on-Severn; the type specimen not being in existence has apparently prevented any reference to similar specimens since that time, and it may be as well to put on record that some few nearly perfect examples of dorsal and other vertebræ, and many portions of others, of the character of those attributed to *Rysosteus Oweni*,[2] have been procured by the writer from Aust Cliff and Westbury-on-Severn, Gloucestershire.

Whether *Rysosteus* be truly a reptile is not mooted at present, until the whole of the material in the writer's possession has been exhaustively examined; but, from the striated character of the neural and hæmal spines, and the characters of the centra of the vertebræ, &c., the resemblance to some amphibian such as *Urocordylus Wandesfordii*[3] is by no means incomplete.

DINOSAURIA.

Phalangeals similar to those from Aust Cliff in the British Museum, and attributed to *Zanclodon* (?), are in the writer's possession, but a fairly large vertebra, 2¼ in. in length by 2 in. in height, exclusive of the neural spine, which is missing, may pertain to *Zanclodon*, or is perhaps more closely allied to *Massospondylus*; in either case this vertebra will be a new record for Britain. Limb-bones, both large and small, are also in his possession, and are provisionally assigned to this order.

6. *On some Forms of Saurian Footprints from the Cheshire Trias.*[4] *By* OSMUND W. JEFFS.

The picturesque quarries in the Lower Keuper (building stones' series), situated at Storeton Hill in Cheshire, have long been familiar to geologists as being the scene of the earliest discovery in England of the famous Cheirotherium footprints by Messrs. Cunningham and Yates in 1839. Besides the impressions of *Cheirotherium* and *Rhyncosaurus* (figured by Mr. G. H. Morton, F.G.S., in his 'Geology of the Country around Liverpool') these quarries yield impressions made by other species of animals, which have been obtained by the author during several years' study of the district. Some of these forms (hitherto undescribed) were exhibited. They include—

(*a*) *Genus non det.*—Slab of Keuper sandstone showing hind and fore feet of a smaller animal than *C. Stortonense*, with narrower toes, which curve inwards and are not separated, nor do they radiate as in true species of Cheirotherium.

(*b*) *Genus non det.*—Tracks of a small animal ⅝ inch in length, with a stubby foot and having very distinct claws on the digits.

(*c*) *Genus non det.*—A still more minute form, ½ inch in length, showing four digits tapering to a point, with no vestige of claws.

(*d*) An oval impression, with concave terminated digits and a hinder projecting 'spur.' Toes webbed. This may be the impression of a chelonian.

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[1] R. Owen, *Rep. Brit. Assoc.*, 1841 (1842), pp. 159, 160; J. Morris, *Cat. Brit. Foss.*, 1854, p. 353.

[2] A. S. Woodward and C. D. Sherborn, *Cat. Brit. Foss. Vert.*, 1890, p. 282.

[3] T. H. Huxley and E. Perceval Wright, *Trans. Roy. Irish Acad.*, 1867, pp. 359–362, pl. xx.

[4] The paper will be published *in extenso* in the *Geological Magazine*.

The author thinks it desirable that some of the more definite forms among the variety found on the slabs from the 'footprint bed' at this quarry should be accurately determined, if possible, instead of being included, as at present, under the general term of 'Cheirotherian.'

The author pointed out that, although fifty years have elapsed since its original discovery, the nature of the animal which made the impressions is still as much a mystery as ever; and that the more we study the known forms of Labyrinthodonts, we are forced to conclude that, whatever was the animal by which the larger five-toed footprints at Storeton were made, it cannot be referred to any known species of Labyrinthodont.

Dr. Tempest Anderson exhibited in the Geographical Section Room a series of lantern slides illustrating the volcanoes of Iceland.

MONDAY, AUGUST 13.

The following Reports and Papers were read:—

1. *Report on Erratic Blocks.*

[Will be published in the Report for 1895.]

2. *Report of the Committee on the High-level Shell-bearing Deposits of Clava, &c.*—See Reports, p. 307.

3. *On some Lacustrine Deposits of the Glacial Period in Middlesex.*

By HENRY HICKS, *M.D., F.R.S., F.G.S.*

In this paper the author refers to some deposits, consisting of stratified gravels, sands, and clay, varying in thickness from a few feet to over 20 feet, which are spread out over the plateaux of Hendon, Finchley, and Whetstone. They are frequently covered over by the chalky Boulder Clay with northern erratics; but seldom themselves contain other materials than those which could have been derived from the Tertiary or Cretaceous series in the south-east of England. No marine fossils of contemporaneous age have been found in these deposits, but remains of land animals occur occasionally in and under them. The author has found that their geographical distribution is much wider than has usually been supposed, and he has been led to the conclusion that they must have been deposited during the glacial period in a lake, whose waters attained to a height of nearly 400 feet above present O.D. This lake, he believes, occupied a considerable area in the south-east of England, and spread for some distance south of the Thames, but was dammed up on the east and west by ice and morainic matter. As the lake became gradually reduced in size, lakelets were formed in the Thames valley, and the stratified deposits now found there, except those in the immediate proximity of the present Thames and its tributaries, date back to that period. Man, however, lived in the valley before any of these deposits were thrown down; hence it is that the flint implements and the mammalian remains usually occur under, or in the lower parts of, the deposits.

4. *On Sporadic Glaciation in the Harlech Mountains.*

By the Rev. J. F. BLAKE, *M.A., F.G.S.*

The author drew a distinction between two results of glaciation—the one, negative, in which the rocks are rounded and striated, and all or nearly all the débris removed; the other, positive, in which the rocks are covered by a thick deposit of drift with boulders. In the Harlech Mountains district areas showing these opposite results lie side by side. Most of the glaciation is of the negative kind, but the areas drained by the Crawcwellt and the Ysgethin are covered by glacial cones of dejection. This difference is accounted for in the first instance by the local drainage being opposite to the general drainage, and in the second by the small size of the gathering ground for the ice. From these results it was argued: 1. That drift deposits are, as a rule, left beyond the area of ice-flow. 2. That no submergence could possibly have taken place here since the Glacial period, or the features above noted would have been obliterated.

5. *On the Probable Temperature of the Glacial Epoch.*
By Professor T. G. Bonney, *D.Sc., LL.D., F.R.S.*

The Alps afford a means of estimating the highest mean annual temperature at which glaciers can begin to form. This must not be more than about 27° F. They also indicate the limits between which glaciers of various moderate sizes form. The author finds that (assuming the present levels of sea and land unchanged) a fall of 20° F. might just bring the Welsh glaciers down to the sea-level, would certainly do it for the Cambrian hills, and would probably produce an ice-shed in the Highlands. A slightly less fall would suffice for the Alps and Pyrenees. Again, a consideration of the traces of glaciers in the Sierra Nevada, Sierra Guadarama, the Apennines, Corsica, Auvergne, the Vosges, and the Schwartzwald shows that these indicate a fall of about 15°, while a greater lowering of temperature would make their glaciers too large. The requirements of North America, New Zealand, Australia, and Tasmania, and other places would be satisfied by about 15°, and in some cases by less. The limits accordingly of the temperature of the glacial epoch must be from about 12° to 20° lower than at present, according to situation.

6. *On the Inadequacy of the Astronomical Theory of Ice Ages*[1] *and Genial Ages.*
By Edward P. Culverwell, *M.A., F.T.C.D.*

In reference to Sir Robert Ball's numbers, 63 and 37, giving the proportion of summer and winter heat in the northern hemisphere, the numbers on which he bases his theory, it is pointed out that in the latitudes with which the Ice Age is concerned the contrast between summer and winter heat is vastly greater than is shown by these numbers, which lump together the heat everywhere, at the equator, the poles, and the intermediate latitudes. Nevertheless, though the arguments on which the theory is based may be made much more clear and striking by taking the heat distribution over the northern part of the hemisphere, the method of calling on the imagination to conceive what vast differences of terrestrial temperature may be produced by a slight change in the daily distribution of the (unchanged) annual heat is dangerous as not being sufficiently based on experience. The argument is that, as the earth is kept at a temperature of, say, 400° F. above zero by sun heat, we might expect a fall of 10 per cent. to lower the temperature by, say, 40° F. But in this argument a number of very important elements are overlooked—the diminished radiation from the cooler body, the great time required for any considerable cooling, and the flow of heat by water and air from the hotter to the cooler parts of the terrestrial surface. In fact, so greatly do these causes modify the result that in these islands we now live without inconvenience in a state of deprivation of solar heat during our coldest 199 days somewhat greater than that which, continued for the 199 days winter of the great eccentricity period, was believed by Sir Robert to involve necessarily an ice age over the northern hemisphere.

The estimation of the change in terrestrial temperature due to the changes of eccentricity made in the author's communication is obtained by an entirely different method. The comparative amounts of solar heat for the various latitudes are calculated (*a*) for the 'glacial' winter of 199 days and (*b*) for the coldest 199 days of our present winter. The result may be expressed thus: In the 'glacial' winter latitudes 40°, 50°, 60°, 70°, and 80° receive about as much heat in their 199 coldest days as 44°·5, 54°, 64°, 74°, and 85° receive in the 199 coldest days at present. Hence, so far as solar heat is concerned, the utmost effect of the eccentricity would be to shift the winter isothermals by 4° to the south, the summer isothermals being shifted by a far greater amount to the north. Hence the astronomical theory cannot account for a shift of the isothermals by more than 4° S. in winter and an average of more than 10° N. in summer—a result ludicrously inadequate to produce an ice age in Great Britain or Ireland, or in the United States, unless, indeed, as a result of the 'glacial' winter, latitude 50° receives vastly less heat from the equatorial regions by air and ocean currents than latitude 54° at present receives in an equal time; and the general principle that the passage of heat to equalise temperature is greater the greater the difference of temperature between the hot and the cold body would, if applicable here, show that 50° in the glacial period should receive even more heat than 50° now, so that we should not expect as great a shift as 4°, even without taking account of the increased summer temperature.

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[1] A paper giving details of the calculation will be published in the *Phil. Mag.*

When we examine the genial age by this method the result is still more remarkable. The calculations in the paper show that the summer and winter isothermals would be shifted by about 2½° only of latitude north and south respectively. It seems entirely out of the question that any change, direct or indirect, depending on so slight a cause could enable walnut trees to flourish in Greenland.

After a further examination of the astronomical theory as put forward by Croll, the paper deals with the relation of existing ice-fields to isothermals, to isobars, and to contour lines; and the belief of the author is that, while no climatic changes due to causes known to be active at present could account for the *genial* age, a local *glacial* period might easily follow from changed barometric conditions, combined with a gradual elevation of land in a northern latitude. Hence it would appear that either genial periods and glacial periods are due to a shift of the pole, or else glacial periods are due primarily to elevation of the land, while the genial age was due to greater solar activity and greater terrestrial heat in the earlier geological ages.

7. *On the Mechanics of an Ice-sheet.* *By* Rev. J. F. Blake, *M.A.*, *F.G.S.*

The author attempted to explain how an ice-sheet can carry boulders up a slope, and leave them at a height of 1,000 feet or more above sea-level. The sides of the channel are, in the first instance, supposed to be parallel, so that the mass of ice may be represented in a diagram by its longitudinal section. Taking for simplicity the shape of the surface moved over to be represented by two straight lines, one corresponding to the slope down from the mountains, the other the slope up from the sea bottom to the final destination of the boulders, and taking the surface of the ice as flat, the ice-sheet is represented by a triangle. This is supposed to settle down in such a way that though the level of the end is higher, the centre of gravity of the whole is lower. This fall of the centre of gravity is the effective cause of the motion of the ice-sheet, the resistance to be overcome being that of the ice to change its shape. If the ice-sheet be supposed divided into strips parallel to the slope from the mountains, these will be like a series of overlapping glaciers, and under the influence of the pressure will swell out at the bottom, and thus push the further end of the whole mass a little way up the counter-slope. Continual additions of snow at the end where the ice-sheet commences, or elsewhere on its surface, will be cumulative in their effects, and thus the further end of the ice-sheet will ultimately ascend as required. Again divide the triangle into strips by lines parallel to the counter-slope. The lower of these strips will be pressed together, and any point on the base will be carried on in the direction of the whole motion at a greater rate than the higher layers, and thus the stones, &c., on the sea bottom will be pushed up to their final resting-place, and anomalies of distribution might thus be accounted for by the previous dispersal of the boulders. It was then shown that differences in shape of the ice-sheet and its spreading out at the further end will make little difference in the argument, and under certain conditions will aid the motion.

The author then discussed the question of the glacial erosion of lakelets, and indicated the conditions under which this is possible, particularly referring to the difference between an ice-sheet such as that dealt with in the paper and an ordinary glacier.

8. *Report of the Committee on the Elbolton Cave.*—See Reports, p. 270.

9. *Report of the Committee on the Calf-hole Cave.*—See Reports, p. 272.

TUESDAY, AUGUST 14.

The following Papers and Reports were read:—

1. *On the Permian Strata of the North of the Isle of Man.*
By Professor BOYD DAWKINS, *F.R.S.*

The main features of the geology of the island are identical with those of Cumberland and Westmoreland. The Ordovician strata form the 'massif' in both areas, and constitute the sea-worn floor upon which the Carboniferous rocks rest unconformably. The Red Sandstone series of Peel, 1,368 feet in thickness, occupies but a very limited area, extending from the Creg Malin, along the sea front, in a line of picturesque cliffs, about one and a half mile to the north-east, and extending inland about 1,700 feet. The rocks may be divided into two distinct groups. First, the Peel Sandstone series, or Rot-Rottodt-liegende, which presents a thickness of 913 feet, and the calcareous conglomerates and breccias of the Stack series, 455 feet thick, representing the magnesian limestone of the Permians. These rocks are faulted into the Ordovician slates, and neither their true base nor their upper boundary is visible. The pebbles of Carboniferous Limestone in the conglomerates point to a post-Carboniferous age, and the physical characters of both divisions are identical with those of the Permian rocks of the North of England, and more particularly with those of the Lake District, of the Vale of Eden and Barrow Mouth, described by Sedgwick, Harkness, Binney, Eccles, and Nicholson. It is clear that north-eastern Ireland, the northern part of the Isle of Man, and the area of the Lake District, including the Vale of Eden, were parts of the same Permian marine basin, in which, as it approached southern Lancashire, the waters became more highly charged with mud, the calcareous element being conspicuous in the one, and being replaced in the other by thick accumulations of marl.

2. *The Carboniferous Limestone, Triassic Sandstone, and Salt-bearing Marls of the North of the Isle of Man. By* Professor BOYD DAWKINS, *F.R.S.*

The Ordovician slates, quartzites, and conglomerates, and the associated volcanic rocks of the 'massif' of the island gradually pass underneath the sand, shingle, and clay of the Boulder Clay series in going northward along the coast towards Kirk Michael, until they disappear altogether from the cliffs and the shore. They stand up conspicuously along the ancient shore line extending from Kirk Michael to Ballaugh, Sulby, and Ramsey, commanding the low, sandy, and marshy region which forms the northern portion of the island, contrasting in its flatness with the lofty rolling Ordovician hills behind, culminating in Sartfell, Snaefell, and North Barule. This contrast is obviously the result of a difference in the physical character of the rocks in the two districts. The problem as to which rocks underlie the glacial strata in the former, which had occupied the author's mind for many years, is now partially solved by the three borings which have been made under his advice by Messrs. Craine in 1891–4 in search of the Coal-Measures of the Whitehaven field, at the Point of Ayre, at Blue Point, and at Lhen Moar. The boring at Lhen Moar revealed the existence of the Carboniferous Limestone at a depth of 167 feet 6 inches below the drift. The next bore-hole, at Blue Point, about 4,050 feet to the north-east of that at Lhen Moar, revealed the presence of more than 60 feet of Red Sandstone buried 171 feet beneath the drift. The Red Sandstone in this section is, in his opinion, identical with the St. Bees sandstone, or lowest member of the Triassic formation in the district of the Lakes.

This conclusion is greatly strengthened by the discovery in the third boring at the Point of Ayre, to the east of the lighthouse, of the Triassic marls with salt, at a distance of a little under five miles from Blue Point. The diamond drill was used from a depth of 452 feet to the bottom. The total thickness of the salt-beds amounts to 33 feet 6 inches, and the bore-hole happened also to intersect a brine run 2 feet 6 inches in depth. If this section be compared with that published by Mr. Dickenson of the saliferous marls of Duncrue, near Carrickfergus, it will be found to be practically identical. The same series of salt-bearing marls is also worked at Barrow-in-Furness and at Preesal, near Fleetwood. The salt-beds in each of these cases are variable in thickness, and those in the Isle of Man are thinner than in the other localities. It must, however, be remembered that the Manx boring has not been put down to a sufficient depth to test the true thickness of the salt-field. The discovery is of great theoretical importance, because it links on the deposit at Barrow to that of Carrickfergus, and shows that the Irish Sea was an area in which the salt-bearing Triassic marls were deposited. It points towards the truth of Mr. Dickenson's suggestion that the Cheshire salt-field was formerly continuous with that of Ireland. These marls have since been broken up, faulted, and denuded away in many places. It is an open question how far those of the Isle of Man are now continuous under the sea eastwards to Barrow and Fleetwood, and to the north-west in the direction of Carrickfergus.

All these rocks are buried under a great thickness of boulder sand, gravel, and clay, amounting at the Point of Ayre to 298 feet. To this also must be added the height of the drift hills close by, formed of the same materials, which would give the total thickness as not less than 450 feet in the extreme north. The rocky floor on which it rests dips rapidly to the north-east towards the deeper part of the Irish Sea.

The discovery of this salt-field is likely to add a new industry to the resources of the Isle of Man.

3. *Strictures on the Current Method of Geological Classification and Nomenclature, with Proposals for its Revision.* *By* Sir HENRY HOWORTH, *F.R.S.*

4. *On the Pleistocene Gravel at Wolvercote, near Oxford.*

By A. MONTGOMERIE BELL, *M.A.*

The section is a typical illustration of a somewhat advanced period of Quaternary time, and in its general features resembles the sections at Hoxne and Bedford, originally published by Sir John Evans, while it is very different from the implementiferous beds of an earlier age which are found on the Greensand escarpment of Kent and Surrey.

(1) The Oxford clay, the bed-rock of the district, is furrowed at the surface into wavy hollows, irregularly filled with earth containing quartz, lydian-stone, and quartzite pebbles, and bunches of unstratified gravel from the Thames basin. It is certainly a northern drift, in the writer's opinion a glacial drift.

(2) At Wolvercote this drift is invaded, and for a certain distance removed by river action, which has hollowed out the clay to a depth of 17½ feet, and subsequently filled up the hollow with horizontal layers of gravel, mud, and sand.

(3) The junction where the river eats into the drift is clearly visible. The bank of drift, underworn by the water, overhangs the horizontal layer.

(4) The lowest bed of the riverine deposits differs from the others: it consists of 2½ feet of gravel and sand, in lenticular, shorn, and current-bedded layers, showing by the size of the pebbles a somewhat rapid current. At the very base, half embedded in the clay, many mammalian bones have been found, and six Palæolithic implements. The implements represent well-known types of the river-valley period, and the mammoth is conspicuous among the animal remains, though *Equus*, *Cervus elaphus*, and *Bison priscus* are also present.

Layers of sand are intercalated with the gravel, from which eleven species of shells have been identified. They are all recent and, generally speaking, stunted in size.

(5) Above the gravel are two inches of sandy peat, marking a land surface of some duration. Nine plants were identified by Mr. Clement Reid, which are all species still to be found in the immediate neighbourhood.

(6) For 14½ feet sand and mud follow in successive layers. In these no fossil has been found. They indicate quiet river action and an increase of pluvial conditions.

(7) Towards the surface they are traversed by an irregular line of trail, which marks apparently the movement of a sludgy mass along the surface, punching it downwards by its weight.

(8) The surface level at Wolvercote is 240 feet above Ordnance datum. The adjacent river surface is 195 feet. The gravel at Somerton and Oxford is about 218 feet. Thus between the two gravels there is a distance of 22 feet. At the present rate of erosion many thousands of years would be necessary to remove 22 feet from the general surface; but the fact that the remains of man and of animals are the same in both gravels proves that they belong to a similar age, though the gravel at Wolvercote is somewhat older than the other. We must therefore consider that the denuding agents—rain and frost—were more active at that period than they are at the present day.

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5. *On Prehistoric Man in the Old Alluvium of the Sabarmati River in Gujarat, Western India.* *By* R. BRUCE FOOTE, *F.G.S.*

Two finds of chipped (Palæolithic) implements were made in a bed of shingle occupying a definite horizon in the lower part of the old alluvium of the Sabarmati in latitudes 23° 25′ and 23° 40′ N. (about 330 miles north of Bombay). The implements were found at a depth of about 70 feet below the surface of the alluvium, which is here over 100 feet thick. The alluvium is overlaid by löss and wind-blown loam, which varies from 80 to 150 feet in thickness. The river has cut itself a bed varying from 100 to 200 feet in depth in these deposits, showing that a great interval of time must have elapsed since the deposition of the old alluvium in which the implements are embedded. On the surface of the löss, and in many cases on the summits of the blown-loam hills, Neolithic remains in the form of flint flakes and cores of the Jabalpur type were found together with fragments of archaic pottery.

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6. *On the Shape of the Banks of Small Channels in Tidal Estuaries.* *By* Professor H. HENNESSY, *F.R.S.*

Many years since my attention was attracted by the peculiar shape of the soft mud banks bordering the channels through which water drains off the beds of, tidal estuaries. These banks, instead of presenting sloping planes or concave surfaces, are always convex when the matter of which they are formed is soft and yielding. A section of such a pair of banks would present an approximation to a cusp in the middle portion.

This peculiar outline is manifestly due to the action of water on the yielding matter. A few years since I found a result which may assist in exploring this phenomenon. The velocity of water in a channel is well known to depend on the ratio of the area of the cross-section to its perimeter. This ratio is variable in all known channels of water flowing through rigid materials such as canals and rivers.

On investigating the form of section corresponding to a constant ratio of the quantities referred to, I found that it would be represented by a pair of catenaries with their ends meeting so as to form a cusp like that in the estuary channels.[1] The result would be that, with every depth of water in such a channel, the flow would have nearly the same velocity.

7. *Report of the Committee on Earth Tremors.*—See Reports, p. 145.

8. *Interim Report of the Committee on the Investigation of a Coral Reef.*

9. *Report of the Committee on Underground Waters.*—See Reports, p. 283.

10. *Report of the Committee on the Marine Zoology of the Irish Sea.* See Reports, p. 318.

11. *On a Keuper Sandstone cemented by Barium Sulphate from the Peakstones Rock, Alton, Staffordshire. By* W. W. Watts, *M.A., F.G.S.*

Professor F. Clowes[2] has described a sandstone from the Himlack Stone, near Nottingham, in which the grains are cemented with crystalline barytes, the amount of this material varying from 28 to 50 per cent. in different specimens. This rock occurs at the base of the Keuper Sandstone of that locality. A somewhat similar rock, occurring at about the same horizon, is described by Mr. A. Strahan,[3] from Beeston Castle in Cheshire, and the same author refers to the frequent occurrence of barytes in the Keuper breccias.

Bearing these facts in mind, the writer visited a curious isolated stack of rock, called the 'Peakstones Rock,' near the village of Alton in Staffordshire, which is figured in Professor Hull's memoir on 'The Triassic and Permian Rocks of the Midland Counties of England.' This stack is made of the lower beds of Keuper Sandstone, but its outer portion has lost whatever cement it may once have contained. It is, however, situated at the end of a spur which projects into a valley, and exposes a good deal of bare rock. This rock contains what at first look like several veins of barytes two or three inches thick, striking along the spur and straight through the place occupied by the Peakstones Rock. On examination of specimens the veins are seen to be planes along which the sandstone is cemented by barytes. The specific gravity of the rock is 3·09, and, as the grains are chiefly subangular fragments of quartz and felspar, it must contain about 28 per cent. of barytes. This almost insoluble cement has undoubtedly given rise to the spur above alluded to, and almost as certainly has caused the survival of the Peakstones Rock, which now, however, is so much exposed to the weather on all sides, and both to mechanical and chemical disintegration, that if any cement is still left it can only be in the inner part of the mass which cannot be reached by ordinary means. Another specimen from 'West of Kent Green, near Congleton,' containing barytes, and with a structure very like that described by Mr. Strahan, was also referred to. The paper was illustrated by a set of photographs which the author owed to the kindness of Mr. A. A. Armstrong and Mr. P. Simpson.

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[1] *Proceedings of the Royal Society*, vol. xliv. p. 108.

[2] *Rep. Brit. Assoc.*, 1885, p. 1038; 1889, p. 594; 1893, p. 732; and *Proc. Roy. Soc.*, vol. xlvi. pp. 363–369.

[3] *Mem. Geol. Survey.* Exp. Quarter Sheet, 80, S.W., p. 7.

12. *Report of the Committee on the Volcanic Phenomena of Vesuvius.* See Reports, p. 315.

SECTION D.—BIOLOGY.

PRESIDENT OF THE SECTION.—Professor I. BAYLEY BALFOUR, M.A., F.R.S., F.R.S.E.

THURSDAY, AUGUST 9.

[For the President's Address see below.]

The following Reports were read:—

1. *Report on Investigations made at the Zoological Station, Naples.* See Reports, p. 335.

2. *Report on Investigations made at the Laboratory of the Marine Biological Association, Plymouth.*—See Reports, p. 345.

3. *Report on the Zoology of the Sandwich Islands.*—See Reports, p. 343.

4. *Report on the Fauna and Flora of the West India Islands.* See Reports, p. 344.

5. *Report on the Index Generum et Specierum.*—See Reports, p. 347.

The President delivered the following Address:—

THE prospect of visiting Oxford to-day has, I am sure, been to all of us a pleasant one, and we who are specially interested in biology have looked forward to our meeting at this time with the distinguished members of the Oxford Biological School. But as we gather here there will, I think, be present to the minds of all of us a thought of one member of that school, whom we had hoped to meet, who is recently gone from it in the prime of his intellectual life. By the death of George John Romanes biological science is bereft of one of its foremost expositors, Oxford is deprived too soon of one whose mental power was yet in its zenith, and each one of us who knew him cannot but feel a deep sense of personal loss; and we shall in our meeting here sadly miss the man brimming with a geniality which robbed differences of their difficulty and charmed away bitterness from those controversies in which he revelled. This is not the occasion upon which to dwell on his character, his merits, or his work. We must all, I think, have appreciated the graceful accuracy with which these were sketched in the pages of 'Nature' by one of his colleagues; but under the shadow, as we are here, of his recent death, I believe I give utterance to feelings every one of you would wish expressed in paying this passing tribute to his memory from the chair of the Section of the Association devoted to the subject of his life-work.

I cannot open the business of the Section without referring to the fact that its organisation appears to be variable, like the objects of its study. It has changed its constitution more than any other Section of the Association, under influences partly from within in the strength of its elements, partly from without in the local circumstances of its meetings. At its origin it was the Section of Botany, Zoology, Anatomy, and Physiology; in the following year anatomy and physiology became a new Section, E, only after some years to merge again in the original one. Then a partition was tried—a physiology department and an anthropology department were formed within Section D; but the Montreal meeting saw anthropology as Section H of the Association and physiology again an integral portion of Section D. This year, as you are aware, physiology—I must be careful to say animal physiology—has again become a definite Section—I. Whether or no the habit thus acquired through the environment of Oxford will be so permanent as to be transmitted and appear at future meetings of the Association is a problem upon which I refrain from speculating; my reason for mentioning this matter at all is to point out that, as in previous devolutions of subjects from Section D, animal physiology is the only physiology which is concerned. It was part of the original proposal that plant physiology should form a portion of the province of Section I. To this the botanical members of Section D are unable to assent. We all readily admit that the development within recent years of our knowledge of plant-life is entirely in the direction of bringing to light fundamental similarities between the vital processes in plants and in animals. To no one do we owe more in this sphere of investigation than to two of the distinguished botanists from Germany whom we are glad to welcome at this meeting—Professors Pfeffer and Strasburger. And we fully reciprocate the desire for mutual comment and criticism implied in the suggestion of combination. But allowing these as grounds for the conjoint treatment of the physiology of plants and animals in one section, what we botanists feel is that we are a compact body of workers in a science the boundaries of which it is at present not difficult to define, and that to divorce physiology from morphology and other branches of botany would tend to loosen our cohesion, would be to go against the current of our progress, and would take all the vitality from our discussions. To have papers on plant physiology dealt with in Section I, whilst those on other botanical subjects were dealt with in Section D, would be not merely an extremely inconvenient arrangement, from causes inherent in the subjects themselves, but would strike at that fraternity and spirit of *camaraderie* amongst those treading the same path of science, the promotion of which is the chief, if not the only, function the British Association now fulfils. At the outset, therefore, of our meetings, I wish to make it known that papers and discussions on all botanical subjects will take place in Section D.

And now I pass to the special topic upon which I am to address you. In selecting it I have followed the lead of those of my predecessors in this chair who have used the opportunity to discuss a practical subject. Forestry, about which I purpose to speak, is a branch of applied science to which, in this country, but little attention has been given by any class of the community. By scientific men it has been practically ignored. Yet it is a division of Rural Economy which ought to be the basis of a large national industry.

There are no intrinsic circumstances in the country to prevent our growing trees as a profitable crop for timber as well as our neighbours. On the contrary, Great Britain is specially well adapted for tree-growing. We have woodlands of fine trees, grown after traditional rule-of-thumb methods, abundant in many districts. The beauty of an English landscape lies in its trees and its pastures. Nowhere in the world, probably, are to be found finer specimens of tree-growth. As arboriculturists we are unrivalled. But the growing of trees for effect and in plantations is a very different matter from their cultivation on scientific principles, for the purpose of yielding profitable crops. This is sylviculture. The guiding lines of the two methods of culture are by no means the same—nay, they may be opposed; and it is the sylvicultural aspect of the science of forestry which has hitherto been neglected in this country. The recognition of this is no new thing. But within recent years it has attracted considerable public attention, as the importance of wood cultivation in our national life has been more realised; and although various proposals have been put forward, and some little effort made for the purpose of remedying the admittedly unsatisfactory state of forestry practice, there has been so far no great result. I attribute this in great measure to the apathy of scientific men, especially botanists, and I am convinced that until they devote attention to forestry the great issues involved in it will not be rightly appreciated in the country.

It is not the first time the subject has been before this Section. I find that in 1885, at the Aberdeen meeting, a committee was appointed by it to consider 'whether the condition of our forests and woodlands might not be improved by the establishment of a forest-school.' The good intention of the promoters was not fulfilled, however. The committee did not meet.

In the first instance, let me briefly refer to the national economic features of forests as they affect us.

There are two aspects from which forests are of importance to a country—firstly, as a source of timber and fuel; secondly, on account of their hygienic and climatic influences.

With regard to the latter, it is a popular notion that trees exercise considerable influence upon atmospheric conditions; but it is only within recent years, and as the result of long experimental research in Switzerland, France, Austria, Germany, and other areas where forestry is practised at a high level of excellence, and also in the United States, that any sufficient data have been forthcoming to form a basis of scientific conclusion upon so important a matter. Although many points are still far from clear, the evidence goes to show that the direct influence of tree-growth upon climate is no mere superstition. Stated in the most general terms, it is proved that forests improve the soil drainage, and thereby modify miasmatic conditions; whilst, like all green plants, trees exercise, through the process of carbon-assimilation, a purifying effect upon the air, the existence of the increased quantity of ozone often claimed for the vicinity of forests is not yet established; by opposing obstacles to air currents, forests prevent the dissemination of dust particles with their contingent germs; they reduce the extremes of temperature of the air; they increase the relative humidity of the air and the precipitation in rainfall, and they protect and control the waterflow from the soil.

To us these effects do not appeal with the same force that they do in Continental areas. Our insular and geographical position renders us in a measure independent of them. The data for these Continental results, it must be remembered, are derived from large forest areas such as do not exist here. For this country I know of no experimental evidence on the subject. As, however, the effects of forest influence are felt mainly in local modifications of climatic conditions, we are not justified in regarding the conclusions that have been reached as inapplicable to Britain. No little interest attaches, therefore, to a statement based upon these Continental observations to which Dr. Nisbet has recently done well to call attention—that 'where the rainfall is over forty inches it is undesirable to increase the forest area.' The significance of this dictum, if it be established, to Britain, dependent so largely upon her agriculture, is evident. Wet years, unfavourable to farm crops, are, under existing conditions, more numerous than favourable dry ones, and any extensive tree-planting in agricultural areas might therefore prove disastrous. But I may here emphasise the point that, whilst for the growing of specimen trees we may agree with Evelyn when he says, 'If I were to make choice of the place or the tree, it should be such as grows in the best cow-pasture, or upland meadow, where the mould is rich and sweet,' yet the harvest which scientific sylviculture reaps comes from land unsuited to agriculture, which would otherwise lie barren and waste, and therefore schemes for the afforestation of such areas in non-agricultural districts need not be prejudiced by the prospect of an increased local rainfall. At the same time we must not fail to learn the obvious lesson that afforestation is not, as some suppose, a simple matter of employment of labour, but that it involves the consideration of weighty scientific problems.

Forests, as a source of fuel, have not the direct importance to this country, rich as it is in coal-supply, that they have in States less favoured, but their economic importance to us as a source of timber needs no comment. There are no means available through which to estimate the annual output of timber from our plantations, but indirectly we can gauge the insufficiency of our woodlands to supply the timber necessities of the country by reference to the returns showing the amount and value of forest produce annually imported. This has been steadily increasing until in 1893 its value exceeded eighteen million pounds. Of course a considerable proportion of the materials thus imported could not in any circumstances be produced in Britain. But, after allowing a liberal discount for these, there remains a large bill which we pay for produce, no small portion of which could be furnished at home. No one would suggest that in the limited and densely populated area of Great Britain timber-trees of kinds suiting our climate could be grown sufficient to supply all our demands; that would be impossible. But few would venture to deny that we could do very much better for ourselves than we do, and that our labour payments abroad might be materially reduced. It is admitted that well-grown home timber is, of its kind, equal to, if not superior in quality to, that which is imported; it is surely, then, legitimate to expect that a large supply of well-grown timber would enable us to hold the market to a much larger extent than is presently the case, and that we might be very much less dependent than we are upon the surplus timber of other nations.

The importance of this to the country is increased by the consideration of the continued appreciation of timber. There is abundant evidence forthcoming to indicate that the present rate of timber consumption of the world is in excess of the present reproduction in the forests of the great timber-supplying countries, and with the persistence of existing conditions we would appear to be within measurable distance of timber famine. Experience, too, teaches that we may expect not a diminution but rather an increase in consumption. No doubt as civilisation advances the discoveries of science will, as they have done in the past, enable us to substitute in many ways for the naturally produced wood other substances prepared by manufacture; but this saving in some directions has been, and will probably continue to be, counterbalanced by greater utilisation in others—witness, for example, the enormous development within recent years of the wood-pulp industry abroad, and consider the prospect opened up by the manufacture of wood silk which is now being begun in Britain.

That the possibility of forest exhaustion is no chimera should be evident to anyone conversant with current timber literature. Taking North Europe for instance:—In Norway, 'raw timber is yearly becoming more expensive and more difficult to obtain.' To Sweden 'pitch pine long beams are taken from America, suitable ones of sufficient size and quality being unobtainable now in Sweden.' In Scandinavia, the virgin forests, 'excepting such as are specially reserved by the Government in the districts where mills are situated, are almost exhausted.' In Russia, the Riga 'supply of oak is exhausted.' These sentences, culled within the past few weeks from trade journals, show that this is a more pertinent question than some would suppose. In Sweden, which, it is remarkable, is actually importing logs from America, the situation is regarded as so serious that proposals are on foot for the imposition of a tax upon exported timber for the purpose of raising a fund for replanting denuded areas. But it is not only in North European countries that there are signs of the giving out of timber forests. As they fail the demand upon Canadian and American stocks increases, and when we look at these Canada 'shows signs of beginning to find it hard to continue her voluminous exports to Europe, and at the same time send sufficient supplies to the United States.' But the most striking evidence is that furnished by the chief of the United States Department of Forestry, in his official report for the year 1892, in which he says: 'While there are still enormous quantities of virgin timber standing, the supply is not inexhaustible. Even were we to assume on every acre a stand of

10,000 feet B.M. of saw timber—a most extravagant average—we would, with our present consumption, have hardly one hundred years of supply in sight, the time it takes to grow a tree to a satisfactory log size. Certain kinds of supplies are beginning to give out. Even the white pine resources, which a few years ago seemed so great that to attempt an accurate estimate of them was deemed too difficult an undertaking, have, since then, become reduced to such small proportions that the end of the whole supply in both Canada and the United States is now plainly in view.'

It must be owned that there are those who do not regard the suggestion of forest exhaustion as a serious one. They argue that the prophecy is no new one, and yet we are none the worse off than we have been; that failing supply from one source it has always been possible to tap another, and so it will probably continue; and then, the period when exhaustion is likely to take place is so far off, there is ample time for the growth of new forests to replace those being cut. No doubt there is time. But this is just the kernel of the whole forestry question. With proper conservancy of forest areas, the application of scientific principles to the recuperation of areas recklessly denuded, and the afforestation of barren and waste lands, timber sufficient to meet a greater demand than is now made could be produced. This is the aim of scientific forestry, and it is to secure this that those who have given attention to the subject are working, conceiving it to be a duty of this generation to hand down to its successors a heritage no less valuable than that which it received.

With an acreage of wooded land amounting to only 4 per cent. of their total area, Great Britain and Ireland possess a smaller proportion so covered than any other European country. Denmark comes near with only about 5 per cent., in France the percentage rises to 15, in Norway and Germany to 25, in Austria-Hungary to 30, whilst in Sweden the amount is over 40 per cent. The United States is estimated to have about 25 per cent. These figures do not, however, give a fair basis of comparison of the amount of timber area in Great Britain with other countries, inasmuch as in the Continental lands the bulk of the woodlands is true forest, whilst a large part of the area included in the British return is merely pleasure ground, and another large portion is only plantation; of real forest the area is extremely limited. It is not surprising, then, that we are not able to furnish ourselves with an adequate supply of timber. But although there is so little land under wood, there are thousands of acres unsuited for any other crop, and these, for reasons I have already indicated, it is desirable to have planted. How to have this accomplished, and how to secure that woodlands already existing shall be tended so as to produce a maximum result, giving a profitable return, are the problems we wish to see solved.

It will conduce to appreciation of the question if I briefly discuss the causes which have been active in developing the present condition of woodlands in Britain, and in bringing about the disparity between it and other countries in respect of woodland area.

State ownership of Continental forests will probably occur to most people as the reason for the difference in area just pointed out. This is true with, however, some qualification. In consequence of the circumstances of their situation Continental States have been compelled to recognise the national economic importance of forests. This they have done, not so much by the creation of State ownership in vast forests as by the organisation of a State Department of Forestry and a State system of forestry education. It is altogether a mistake to suppose, as is often the case, that the whole or even a large part of the forests on the Continent belong to the respective States. The amount of State-owned forest is surprisingly small. Fernow gives it in Germany as about 33 per cent. of the whole forest area, in Scandinavia 15 to 20 per cent., in France some 10 per cent., in Switzerland 4 per cent., whilst in Italy it is not 2 per cent. The bulk of the forest is in the hands of private owners or corporate bodies, subject, though apparently not always, to some control or limitation by the State. But the example of the States in the management of their own woods, their readiness to give advice through their officials, and the education which is carefully provided for those concerned in forestry work, have resulted in those privately-owned forests being as well managed as those of the State. It is important to make clear this distinction, because it shows that a State system of conservancy and supervision of forestry is quite compatible with large private ownership in forests, and that efficient sylviculture upon a large scale is not inseparable from State ownership.

But someone may say, 'We, too, have State forests!' Yes, but it is almost absurd to mention them in the same sentence with those of the Continent for any part they play at present in connection with forestry in Britain. The nine thousand acres at Windsor are mainly covered with specimen trees. Of the twenty-five thousand acres in the Forest of Dean, a portion is supposed to be cultivated for a profitable crop, but appears to result in an annual deficit. The New Forest, with its sixty-three thousand acres of soil-area, affords us one of the most interesting object-lessons, showing the triumph of sentiment over common-sense, that the country affords. Its history is well enough known, and I need only remind you that Parliament has decreed the major part of it to persist as a barren waste, whilst in the remainder which is covered with trees the practice of forestry is prohibited, so that slowly the whole is going to wreck and ruin. This illustrates the value to us of State forests! In the days of the 'wooden walls' the dockyards obtained valuable timber from them, but now their large area is, one may say, of no State service whatever as forest, if one excepts a small portion of Windsor Forest recently attached for instruction purposes to Coopers' Hill College. There can be no question that if the State had set an example of scientific forestry in even a portion of these areas, the practice of sylviculture now throughout the country would have been very different.

I need not dwell on the fact that the conditions of land tenure in the country have exercised an important influence upon the extent of wood-planting in the country; and they must always do so. 'The oak scorns to grow except on free land' is a saw that sums up pithily the relationship between land-laws and woodlands in England. Copyholders could hardly be expected to plant much timber when the lord of the manor claimed the crop; and I believe it is possible in some counties to trace the boundaries of copyholds by the entire absence of trees on one side of a line and their luxuriant growth on the opposite side. The intricacies of entail and the fact that life-renters had themselves to bear the expense of planting, except where necessary for shelter, without prospect of seeing a return for the outlay, must have operated prejudicially to an increase in woodlands. Happily, since 1882 in England, and by an Act of last year for Scotland, the last-mentioned restriction upon tree-planting is removed.

Nor shall I pause over the question of game, which has been at once the origin and the destruction of forests in Britain. Not that it is an unimportant element. But the instinctive love of sport in the British race is proof against all argument of utility, and the needs of sport will always be a barrier, as they have been in the past, to the planting of large areas well adapted for timber-growing. It cannot well be otherwise. Landowners can hardly be expected to forego large and immediate game-rents for what appear the long-delayed, even though possibly greater, profits of timber-cultivation. In this case the inevitable must be accepted. Nevertheless, there are large areas, the game-rent of which is infinitesimal for their acreage, which might be planted.

The most potent factors in bringing about the present condition of our woodlands are probably to be looked for in the nature of the crop itself and in the want of appreciation of its character manifested by landowners; in a word, in a want of knowledge of the principles of scientific forestry. Forestry is handicapped as compared with agriculture by the fact that the crop cannot be reaped within the year. The owner who plants and incurs the initial expense of stock, fencing, and perhaps draining, may after some years secure intermediate return from thinnings, but it will rarely happen that he reaps the final yield at maturity of the crop he has sown; it will fall to his successor. It is this planting for posterity that makes demands upon the landowner to which he is unequal. Hence it comes about that woodlands, beyond what may be requisite in the way of cover plantation and for shelter, are often regarded as expensive luxuries, and, in the time of high agricultural values, landowners have even grubbed out trees to make way for annual crops yielding an immediate return. But scientific tree-growing for profit does not consist in the covering of soil area indiscriminately with trees, without definite system and relation of its part one to the other. Just as the farmer has to plan his rotations on a definite system with reference to his total acreage, so in properly managed timber-growing must areas be arranged in such a way that some part of the forest will be yielding annually its final return of mature crop, and cleared areas will by a natural process of regeneration replenish themselves without recourse to the expensive operation of planting being necessary. Scientifically worked, a forest area on suitable land, of which there is such abundance in Britain, should be capable of yielding an annual net revenue as regular as that obtainable by any other form of soil cultivation.

It is nevertheless frequently urged as a reason for not growing timber that wood will not pay in Britain. A landowner will tell you he has acres of land which do not return him more than half a crown, and if it would pay better he would be glad to put them under timber, but he does not believe it would; and he will point to rates on woodlands which must be paid although no crop is being reaped. He will demonstrate that there is no market for home timber, which seldom fetches its value, and that there is a prejudice against it which increases the difficulty of any attempt to compete with the foreigner.

There is some reason in the latter part of this contention. The wood-grower in Britain has, I think, just cause for complaint when he finds his produce not only handicapped by preferential transport rates to foreign timber, as has been the case in the past, but that it is also disparaged by exclusion from, or admission only under conditions to, competition with foreign timber by the terms of building specifications. It is said to be the common practice of architects and others to bar home timber in this way, and the Government itself has not been guiltless in the matter. The Post Office form of tender a couple of years ago for telegraph poles entirely cut out native produce from competition, and the conditions of contract framed by the Board of Agriculture under the Land Improvements Act were until recently almost prohibitive to home timber. These latter are now modified, but whether or not the Post Office still boycotts home produce I cannot say.

However it is come about—and there are no doubt various effective causes—this undervaluing of home-grown timber is quite unreasonable, and the slur cast upon it is undeserved, so far as its quality is concerned. At the same time, there is ground for saying that the difficulties, occasioned in this and other ways, of disposing of home timber at remunerative prices are due to causes not altogether beyond the control of landowners who grow timber.

It is generally admitted that with a more regular and certain supply, as well as a larger amount in different districts, home timber would have a better chance of holding its own in the market. This is just what scientific forestry would bring about. Given a systematic cultivation of forest on scientific principles of rotation, and the conditions are prepared for a steady output of timber by annual cut, as well as for a supply of raw material for utilisation in the manufacture of the many subsidiary products derivable from forest growth. If landowners would only provide such supplies, they would alter altogether, and to their own advantage, the conditions under which they dispose of so much of their home wood. The timber merchant who now travels hither and thither over the country picking up small lots where they may occur for transport to his, probably distant, mills, at a cost which eats a big hole in the value of the trees to the landowner, would find it worth his while—and, for that matter, it would be worth while for the landowner himself—to erect, in the vicinity of the forest, mills for the purpose of converting and preparing the timber, and to put up machinery for the extraction of useful products from the waste wood. In such conditions a steady market could be created in which the advantage would lie altogether on the side of the home-grown article, and materials, the *débris* of the forest, now thrown aside as useless would be turned to account to the greater benefit of the landowner. Encouragement, too, would be given to the establishment of local industries dependent upon forest growth, through which fresh outlets for forest produce would be provided.

The amount of profit returnable from timber cultivation must of course vary with the circumstances of the area in each case, but in comparing values it must always be borne in mind that timber land is land which can yield no agricultural rent. The official statistics relating to Continental State forests show us the result of forestry on a large scale, and it is interesting to note how, under what we must believe to be an equally efficient system of forestry management, the net revenue from the several areas differs greatly. Thus from its two million acres of forest area Bavaria draws a little over five shillings per acre per annum; Wurtemberg, with nearly half a million acres, gets a return of about eleven shillings; and Saxony, with a somewhat less area, receives over seventeen shillings per acre per annum. For this country we have no such figures. Our State forests result in a loss. It is unfortunate, too, that no returns are available from private forests and woodlands, either in Britain or abroad. Estimates of possible profits in this country we have abundantly, but solid figures of expenditure and receipt in relation to timber-growing there are none. By the favour of Mr. Munro-Ferguson, M.P., who, as a landowner, exhibits a most enlightened spirit in regard to forestry, I am, however, able to cite the case of a pine and larch wood at Novar, in Ross-shire, twenty-four acres in extent, which was clean cut in 1883, and gives instructive figures. After sixty-one years' growth on land similar to that which in the neighbourhood yields a grazing rent of from one to two shillings per acre, it is found to have yielded a net sum equal to a revenue to the landlord during the whole period of its growth of over nine shillings per acre per annum, or an increased value of quite seven shillings per acre per annum. Although it refers to only a single wood of limited extent, this return shows how profitable waste land may become under timber. No doubt from the estates of other of our landlords who own extensive woodlands, where, if there is not the highest scientific forestry, there is certainly good wood management, results of an equally instructive kind could be obtained—many would be better; and it is much to be desired in the interest of forestry that they should be made known as an object-lesson to those who doubt the profit of tree-growing.

But in the return I quote from there is another interesting point which I must not fail to note. During the period of growth of the wood, the outlay upon labour in connection with it amounted to a sum equal to an expenditure of over thirty-one shillings per acre per annum. That is to say, this sum was distributed in wages to the people of the neighbourhood. This exhibits the benefits brought in the train of forestry, which are no less important to the community at large than is the profit of the crop to the landowner. The scientific treatment of woodlands and cultivation of forests for profit on a proper scale involve the employment of a considerable amount of labour, much of it at a time when there is little else doing in country districts, not only in the actual tending of the forest area, but in the manipulation and subsequent preparation of the timber, and in the manufacture of the numerous by-products obtainable from it. In these days of congestion in cities the importance of the development of such an industry which can provide occupation in the country, and thus may aid in restraining migration to the towns, has not escaped notice, and it cannot be too often or too greatly emphasised.

The influences, to which we have just given attention, that have prevailed in bringing about the present limited area of woodland in Britain are, it will be seen, not wholly irremovable, nor are the obstacles to betterment insurmountable. And the question we have now to discuss is—How are these to be counteracted and overcome? By what means is it possible to bring forestry in Britain more in line with that of other nations? At the outset I would say that if forestry is to be established on a sound commercial basis, the only one on which it should rest, if we are to have a national home-timber industry, it can only be when the issues involved are more fully realised than they are nowadays. As in agricultural practice failure can only be obviated by the application of scientific methods in farm cultivation, so is it with forestry. To become a profitable industry it must be practised as an applied science, and not as an empirical routine.

We live beyond the days when it would be possible to apply the autocratic remedy for want of woodlands introduced in Scotland by the Jacobean statute, which compelled the landlords not only to plant wood and forest and make hedges, but also enjoined them under penalties to see that each of the tenants planted one tree for every marke of land. Nor, indeed, can much be said of the success of the compulsion. And I do not imagine anything could be gained nowadays by the method adopted in Scotland in the middle of last century by the 'Select Society,' as it was called, of offering a premium to farmers who planted the most trees within a specified time. That such processes were deemed necessary is interesting as showing how old standing has been the recognition of the want of sufficient woodland area in the country. At the present time there are those who would reverse, as it were, the process of the old statute, and who look to the acquisition by the State of large areas of waste land, and their afforestation by it, for the solution of this forestry question. It is, no doubt, a wise policy which encourages private enterprise to deal with the details of industries, and only invokes State aid as a directive and controlling force when its need can be clearly shown. That there is need for State aid in the case of forestry I do not deny, but it is not required to the extent just mentioned.

I unhesitatingly say that the State ought to treat the forest areas now in its possession in a reasonable and scientific manner, instead of leaving them as objects for the finger of scientific scorn. They might be made, in part at least, models of the best forestry practice. It is no use to dispute with the sentiment and taste which have prevailed in making the New Forest what it now is, and it is hopeless to expect a unanimous verdict as to the destiny of State woods and upon the method of treatment to which they should be subject. We have had recently, in the lively discussion regarding the management of Epping Forest, an illustration of how large is the number of people who have views upon the subject of the management of woodlands, and how the majority of them, if they had their way, would, through ignorance, defeat the very object they desire to accomplish. We must be prepared in any proposal for utilisation of State forests to incur the opposition of those who regard all scientific handling of woods as vandalism, although I do not know that forestry in itself involves a want of recognition of the beautiful, or dulls the feelings which a sylvan landscape invokes in the minds of those in touch with Nature. It is allowed there are areas in our State forests sacred by many memories, possessing a grandeur and picturesqueness with which no hand, whether of forester or landscapist, would venture to meddle. But, on the other hand, there are tracts which without damage to the natural beauty, and without depriving in any sensible degree the people of their privileges of recreation they prize so much, might be and should be dealt with as forest cultivated on scientific principles. These might serve as instruction areas, showing all that is best for the information of foresters. The creation of some such experimental teaching stations in State forests is one of the essentials for forestry in Britain. I would go further and say that the area of State ownership should be increased to the extent of the establishment of forest stations, of an acreage sufficient to allow of a satisfactory rotation, in other parts of the country as centres of instruction. There have been, as you are aware, proposals for the afforestation of some of the three million and more acres of waste land in the Highlands of Scotland capable of growing timber, and we await with some interest the report of the Deer Forest Commission, which has taken evidence on the subject. If, as has been suggested may be possible, afforestation is attempted through any system of State-aided planting, an opportunity would be afforded for securing what would be of so much advantage to the country. Beyond this system of model experimental stations, the State ownership of forest in Britain does not seem to me to be necessary in the cause of forestry.

Replying recently to Sir John Lubbock in the House of Commons, the President of the Board of Agriculture, after recounting what his Board is now doing for forestry in Britain, added: 'I shall always be glad to receive and to consider any suggestion for the increase of sound technical knowledge on this subject.' Well, now, I have a suggestion to make. In a practical science like forestry 'an increase of sound technical knowledge' can only be possible when facilities for practical instruction are provided. I would, therefore, ask the President to consider what I have just said with regard to State forest experimental areas. These cannot, of course, be created by a stroke of the pen, but the initiative for their formation would naturally come from the Board of Agriculture. It is possible that, with betterment in forestry practice, landowners might be found who would be willing to devote portions of their land for the purposes of instruction, following for forestry the noble example of Sir John Lawes in his work for agriculture; and everyone interested in forestry must hope this may be so. But when the State has already in its hands the means through which a large national industry can be fostered, it is surely incumbent on it to utilise them for the purpose. And mark you, in asking for this, one does not make a large demand upon the Treasury. The whole could be done at no ultimate cost, for the profits from the areas could unquestionably more than repay any outlay incurred upon them.

The true solution of the forestry question in Britain is to be found in the diffusion of accurate knowledge of forest science. The landowner has to be convinced that through scientific forestry a sound and profitable investment for his capital is to be found in woodlands; the factor or land agent must be instructed in the scientific principles of tree-growing for profit to enable him to secure a steady income to the landowner from his invested capital; and the working forester has to be taught methods of cultivation based upon science, by which his faith in traditional practice, when it is, as is so often the case, unscientific, may be dispelled. It is through education alone that we can arrive at improved forestry.

This was recognised by the Select Committee upon Forestry of the House of Commons in its report in 1887, which performed a very valuable service by its exposure of the prevalent ignorance of scientific forestry and of well-known facts of tree-cultivation amongst those professedly engaged in its practice and study—an ignorance the continued existence of which manifests itself in some of the writings in current periodicals. The remedy it suggested of a State Forest Board, including representatives of science and of bodies interested in forestry, charged with the superintendence of the formation of forest schools and the preparation of forest literature, was superseded by the later institution of the Board of Agriculture, in which were absorbed such functions in regard to forestry as the Government of the day accepted. We are so accustomed to anomalies in our administrative system that the discovery of an additional one hardly surprises us. Yet it is difficult to understand why it is that a board which deals with subjects so essentially based on science as does the Board of Agriculture should not have on its staff scientific men representative of the fields of science within its purview. But I do not know that either agriculture or forestry is so represented. It seems odd that this Board should be dependent for scientific advice upon outsiders, and now that it proposes to undertake the responsibility of the publication of a journal which, I take it, will be a means for the circulation of accurate information upon scientific questions, I do not see how its functions can be adequately performed without scientific help from within. No one of us would expect to see, either to-day or to-morrow, in this country a Board of Agriculture with an organisation like that of the similar department in the United States, which excites our admiration by the excellence of the practical information it circulates. But there is a wide interval between the completeness of the American department and the incompleteness of ours; and if I may make another suggestion to the President of the Board of Agriculture, I would ask him to consider whether it would not strengthen the Board in the discharge of its rapidly growing functions if it had competent scientific advisers upon its staff. Such a man for forestry would, I believe, do much for 'the increase of sound technical knowledge' in Britain, and promote to no little extent its interests.

Since 1887 we have made some advance along the lines of improved literature and of teaching pointed out by the Select Committee as those by which reform could be accomplished.

If one looks at the literature available up to a recent period to anyone desirous of learning something about forestry, one need feel little surprise at the ignorance which prevailed. It was alike meagre in amount and deficient in quality, consisting chiefly of the records of empirical practice of men who had had no scientific training. It is satisfactory to note that these are now being replaced by works having some pretension to scientific method and accuracy. From Cooper's Hill there is issuing, more slowly than could be wished, Professor Schlich's excellent 'Manual of Forestry,' and from his colleague Professor Fisher we may, I believe, soon expect an important forestry book. You all know Professor Marshall Ward's lucid little books on timber and plant-diseases, and we are promised immediately, under his editorship, a translation of Hartig's 'Diseases of Trees,' by Professor Somerville. A most valuable and interesting contribution to forestry literature is the book by Dr. Nisbet, recently issued from the Clarendon Press, containing the lectures he delivered in the University of Oxford during the past year; and to his marvellous energy we shall owe the new edition of 'Brown's Forester,' which is shortly to appear, and an English version of Hartig's 'Text-Book' for foresters. All this activity shows an increasing interest in forestry, but it is only the beginning of a movement to make up for the preceding dearth. Botanists are greatly indebted to the Delegates of the Clarendon Press—and it is fitting I should here acknowledge the obligation—for the splendid series of standard foreign works on botany they have brought within the reach of English-speaking students, and which have done so much for the progress of botany in Britain. If we have now got beyond the stage of dependence in pure botany, we are far from it in scientific forestry, and I would hope that the Clarendon Press will add to its botanical series some of the standard foreign forestry books, and thus aid in the dissemination of the knowledge so essential to progress in the subject.

I must not omit to refer here to the excellent opportunity that is afforded for the circulation of scientific information by the new journal of the Board of Agriculture, of which intimation has recently been made, and it is to be hoped that forestry will find a place in it side by side with agriculture.

The attention paid to the teaching and study of forestry by Continental States, their many schools and copious literature of forestry, make it remarkable that, apart altogether from the economic side, forestry as a subject of study and investigation has not been long ago introduced in some of our teaching centres. I think the Sibthorpian Chair of Rural Economy of the University of Oxford was for long the only one through which forestry was recognised as within the sphere of university education. So far the limited tenure of this chair, in its new dress, has been held by agriculturists—in their line the most distinguished men; but I should like to think that one may look forward to a time when forestry shall have its turn, if by that time it has not come about that it is otherwise provided for.

It was, however, only the necessities of India which, at a comparatively recent date, led to the first starting of forestry teaching in Britain, and then only at the cost of India, and for those destined to serve there as foresters. Cooper's Hill College, the outcome of these, with its excellent equipment—including now, I believe, a slice of Windsor Forest for purposes of practical work—possesses the elements of a successful forestry school, and it has within recent years opened its doors to outsiders who may wish to learn forestry. But, so far as I am aware, it does not draw the young landowners of the country as it should do. Possibly the expense of the special education, which equals that of the universities without offering the advantages in other directions they afford, may be deterrent; but I am inclined to think that if the authorities made the fact better known that men other than foresters for India are admitted to the college, more would avail themselves of the opportunity.

Beyond this and some slight notice of forestry at agricultural colleges, there have been no facilities for forestry-teaching in Britain until within the last half-dozen years. I leave out of reckoning mere examining boards. Can we wonder, then, that there is a general want of intelligent appreciation of scientific forestry? Even now all that has resulted from the agitation in favour of more attention being given to this subject is—a lectureship on forestry in the University of Edinburgh, supported partly by the Board of Agriculture and partly by an endowment from subscriptions among landowners and others (and, I may mention here, forestry is now included as an optional subject in the university curriculum for an agricultural degree); a chair, or part of one, in the Royal College of Science at Newcastle, founded conjointly by the Board of Agriculture and the County Council; a course of instruction in science for practical foresters in the Royal Botanic Garden at Edinburgh, maintained by the Board of Agriculture; and a lecture course on forestry in the Glasgow and West of Scotland Technical Institute, similarly provided for. I must not omit to mention, too, the beginning, just made, by the Surveyors' Institute of the formation of a forestry museum in London, which should have an important educative influence. Little though it is, I think there is occasion for congratulation that even so much has been done to provide instruction, and I would have you note that in this education the different classes concerned with forestry are all recognised. Valuable as the teaching so being given is, it must have an effect in showing the need there is for more. In one way the teaching of all these bodies is incomplete, and must be imperfect, inasmuch as they have not the means for practical forestry work. Until this is provided, as I have indicated already, the teaching of forestry cannot be thoroughly carried out.

But, after all, what has been done in the way of supplying our wants in the way of teaching is nothing to what is required if forestry is to be adequately taught in Britain. Dr. Nisbet, who, in his book already mentioned, has had the last say on this question, boldly states the requirements at six forestry chairs in universities, and four schools of practical sylviculture in the vicinity of forests. I do not think he put the needs one whit too high. I should be even disposed to add to them, because I note he has omitted to take into account the claim of Wales, whence there has recently been a request for the establishment of forestry teaching.

But there are two questions strictly pertinent to this demand, which need answering if the proposals are to be brought within the sphere of practicability—firstly, whence are the funds to be obtained for this organisation; and, secondly, where are we to get the teachers?

Dr. Nisbet puts his hand in the Treasury pocket for the money—some five thousand pounds per annum—required by his scheme. I do not think many of us will be so sanguine as to expect the whole financial aid could be directly obtained in this way. But it may be, I think, of significance in regard to this to consider the sources from which money has been forthcoming for what has already been done. The Government, through the Board of Agriculture, has given most, the remainder has come from the County Councils and from private contributions.

There is no reason to suppose the Board of Agriculture will be less willing in the future than it has been to aid in the establishing of forestry teaching in suitable centres; but its support from the limited funds—eight thousand pounds—at its disposal for educational purposes is always given as a grant in aid, and is contingent upon evidence of local effort towards the end desired, which we must therefore look to in the first instance.

It is of no use to speculate upon the prospects of private munificence providing equipment in any centre. We may hope for it, but I do not think times are such as to lead us to expect large pecuniary aid from landowners. After vigorous effort amongst them, extending over some years, to secure an endowment for a chair of forestry in Edinburgh, a sum of a little over two thousand pounds is all that has been raised.

But forestry is one of those subjects to the teaching of which we may be more sanguine of support from County Councils. It will always be a matter of regret to scientific men, and those interested in the industrial progress of the country, that the grand opportunity furnished by the fund dealt with under the Local Taxation Act (1890) was not taken more advantage of by the Government of the day. Distributed, even in part, through representative educational institutions, it could have provided equipment for technical education of the highest kind beyond our dreams. Thrown at the heads of the County Councils, before these bodies had had time to settle to their prescribed work, there has been, in the opinion of those well qualified to judge, no little waste. You could not create all at once the machinery requisite for the most efficacious expenditure of half a million of money on technical teaching. Much of the work done by these bodies is admirable. It is indeed surprising in the whole circumstances how efficiently technical instruction has been carried out, and no doubt it will improve. But it had a most extravagant start. It is difficult to trace, in the general returns of the technical education undertaken by the County Councils, the details of their work, and I have not been able to discover how far forestry has been treated as a subject of instruction. It has not, I think, been often included. But the example of Northumberland and Durham in respect of the Newcastle chair is one that gives encouragement for thinking that, if the due importance of forestry to the community were made clear, County Councils, in districts favourable for forestry and its concomitant industries, might come forward with some of the financial support needed for the provision of the educational equipment.

It appears to me that whilst we must obtain from the Government the institution of sylvicultural areas for practical instruction, our best chance of success in acquiring the necessary endowment for the rest of the teaching lies in the line of combination between the Board of Agriculture and the County Councils, with, it may be, aid from private benefactors. But if we were to draw financial support from County Councils, or from private sources, we must as a first step towards this make known, more thoroughly than it is, the nature of the national interests involved. We must disabuse landowners, land agents, and practical foresters of the notion that forestry consists in the random sticking in of trees, which anyone, no matter how unskilled, may accomplish. We must bring home to the people's minds that in science is to be found the only sure guide to proper timber-growing, and that scientifically managed forests are alike a profit to the producer, a benefit to the community of the region in which they are reared, and a source of national wealth. Once we have got so far as to create this opinion, the funds for as extended a scheme of forestry education as may be necessary will, I venture to think, be forthcoming.

There is still the other question to answer—Whence are the teachers to come? This is, I think, fundamental. For, given a competent teacher, he will soon find opportunity for teaching. If to-morrow the whole or even a half of the chairs suggested by Dr. Nisbet as essential were founded, how should we meet the demand for men to fill them? We might, of course, draw upon the Indian Forest Service, but I do not know where you would find teachers in Britain. But if there is no prospect of such immediate requirement of teachers, that does not make the fact of their deficiency of any less moment. There is surely something wrong when men capable of giving scientific instruction in so important a practical subject are so scarce.

This is how it touches us botanists, and upon our shoulders I am disposed to throw the blame for the present outlook. We do not seem to have realised, except in relation to medicine, that modern botany has an outlet. Perhaps it has been the influence of medicine that has engendered this. We find chemists and physicists devoting their science to the furtherance of practical aims. Zoologists have applied theirs to the elucidation of problems bearing on the fishery industry; and we see in that monument to the ability and energy of Professor Ray Lankester, the marine biological laboratory at Plymouth, an experimental station which, while it contributes to the nation's prosperity, serves at the same time as a home of pure research. But where is the practical outcome of modern botany? I must not overlook such brilliant work as that of Marshall Ward, full of purpose, and significant as it is to many large industries, nor that of Oliver in its bearings on horticulture. But it does seem to me that the general trend of botanical work in Britain is not utilitarian. Perhaps as good an illustration as could be given of the slight practical importance attached by the lay mind nowadays to botany is the fact that the Scottish Universities Commissioners have made it—though I must add it is bracketed with zoology—optional with mathematics for the degree in agriculture!

It is matter of history that its utilitarian side gave the first impetus to the scientific study of botany. The plant-world, as the source of products of economic value and drugs, attracted attention, and out of this grew, by natural development, the systematic study of plants. The whole teaching of botany was at the first, and continued for long to be, systematic and economic, and it was from this point of view that, the herbalist having become the physician, botany became so essential a branch of medical study. It is noteworthy that as an early practical outcome of the study came the establishment of botanic gardens, which, at their institution, were essentially what we would now style experimental stations, and contributed materially to the introduction and distribution of medicinal and economic plants, and to the trial of their products. If they are now in many instances simply appendages of teaching establishments, or mere pleasure-grounds, we at least in Britain are fortunate in possessing an unrivalled institution in the Royal Gardens at Kew, which still maintains, and under its present able Director has enormously developed, the old tradition of botanic gardens as a centre in our vast empire, through which botany renders scientific service to our national progress.

In Britain, consequent perhaps on our colonial and over-sea possessions, the systematic side of botany continued predominant long after morphological and physiological work had absorbed the attention of the majority of workers and made progress on the Continent. Not that we were wanting in a share of such works, only it was overshadowed by the prevalent taxonomy, which in the hands of many no longer bore that relation to its useful applications which had in the first instance given it birth, and had become little more than a dry system of nomenclature.

The reaction of a quarter of a century ago, which we owe to the direct teaching of Sachs and De Bary and the influence of Darwin, many of us can remember: in it some who are here to-day had a share. Seldom, I think, is a revolution in method and ideas of teaching and study so rapidly brought about as it was in this instance. The morphological and physiological aspect of the subject infused a vitality into the botanical work which it much needed. The biological features of the plant-world replaced technical diagnosis and description as the aim of teachers and workers in this field of science. No weightier illustration of the timeliness of this change could be found than in the attitude of medicine. But a few years ago he would have been rash who would predict that botany would for long continue to be recognised as a part of university training essential to medical students. Its utility as ancillary to materia medica had lost point through the removal of pharmacy from the functions of the physician. But what do we see now? Not the exclusion of botany from the university curriculum of medical study, but the recognition to such an extent of the fundamental character of the problems of plant-life, that it is now introduced into the requirements of the colleges.

But if the old taxonomic teaching was stifled by its nomenclature, there is, it seems to me, a similar element of danger in our modern teaching, lest it be strangled by its terminology. The same causes are operative as of old. The same tendency to narrowing of the field of vision, which eventuates in mistaking the name for the thing, is apparent. With the ousting of taxonomy, and as the laboratory replaced the garden and museum, the compound microscope succeeded the hand-lens, and for the paraphernalia of the systematist came the stains, reagents, and apparatus of microscopical and experimental work as the equipment necessary for the study of plants, the inwards rather than the outwards of plants have come to form the bulk of the subject-matter of our teaching, and we are concerned now more with the stone and mortar than with the general architecture and plan of the fabric; we are inclined to elaborate the minute details of a part at the expense of its relation to the whole organism, and discuss the technique of a function more in the light of an illustration of certain chemical and physical changes than as a vital phenomenon of importance to the plant and its surroundings. This mechanical attitude is quite a natural growth. It is a consequence of specialisation, and it is reflected in our research. But it must be counteracted if botany is in the future to be aught else than an academic study, as it was of old an elegant accomplishment. It has come about very much because of that want of recognition by botanists, to which I have already referred, of the natural outlets of their study—of their failure so far to see the lines through which the subject touches the national life. Modern botany has not yet found in this country its full application. It has not yet rendered the State service as it ought, and as was done by the taxonomic teaching it supplanted.

It is from this point of view that I wish to point out to you to-day that through forestry—and although I have particularly dealt with this branch of Rural Economy, what I say is equally true of horticulture and agriculture—modern botanical study should find a sphere of application by which it may contribute to our national well-being, and which would have a directive influence upon its teaching, taking it out of the groove in which it tends to run. What we botanists need to do in this connection is to teach and to study our subject from a wider platform than that of the mere details of individual form, and to encourage our pupils to study plant-life not merely in water-cultures in the laboratory, but in the broader aspects exhibited in the competitive field of Nature.

If forestry is ever to thrive in Britain botanists must lay the foundation for it in this way. We cannot expect to make our pupils foresters, nor can they yet get the practical instruction they require in Britain. In this we must depend yet a while on Continental schools; the stream of Continental migration, which needs no longer to flow in morphological and physiological channels, must now turn in the direction of forest schools. But we can so mould their studies and give bias to their work as will put them on the track of this practical subject. If we had only a few men so trained as competent foresters, and capable of teaching forestry, there would be an efficient corps with which to carry on the crusade against ignorance and indifference, the overcoming of which will be the prelude to the organisation of forestry schools and scientific sylviculture in Britain. The influence of the individual counts for much in a case like this. The advent of a capable man started forestry teaching in Scotland, which years of talk had not succeeded in doing. And so it will be elsewhere.

I have endeavoured, thus briefly, to sketch the position, the needs, and the prospects of forestry in Britain. Its vast importance as a national question must sooner or later be recognised. It is a subject of growing interest. Its elements are complex, and it touches large social problems; but the whole question ultimately resolves itself into one of the application of science. To botanists we must look in the first instance for the propagation of the scientific knowledge upon which this large industry must rest. They must be the apostles of forestry. And forestry in turn will react upon their treatment of botany. Botany cannot thrive in a purely introspective atmosphere. It can only live by keeping in touch with the national life, and the path by which it may at the present time best do this is that offered by forestry.

The Section was then divided into two Departments: (1) Zoology, (2) Botany.

Department of Zoology.

The following Papers were read:—

1. *On the Didermic Blastocyst of the Mammalia.*

By Professor A. W. W. Hubrecht, *LL.D.*

It is a fact that about the simple and early didermic stage of the mammalian blastocyst very divergent views are at the present moment held by different observers. Only lately an English embryologist, who with great technical skill has considerably added to our knowledge of the development of the mouse, brought forward certain ingenious speculations concerning this didermic stage in other mammals besides those with which he was personally acquainted. The author referred to Dr. Robinson's paper in vol. xxxiii. of the 'Quarterly Journal of Microscopical Science.'

According to these views the outer layer of the monodermic blastocyst is in reality a hypoblastic layer. The didermic phase essentially originates out of this by a gradual spreading of epiblast cells outside the more primitive hypoblastic wall.

However ingenious these speculations may be, the author holds them to be erroneous.

As an example of a mammal the early development of which furnishes us with decisive evidence in this respect, the author wishes to call attention to *Tupaja javanica*, a small insectivorous mammal from the Malay Archipelago, of which a stuffed specimen was exhibited.

Of this mammal the author possesses a most complete series of preparations of the early developmental phases, including the extrusion of the polar bodies, the fecundating process, the segmentation, &c. Selections from these preparations were brought over by him to the meeting, which were demonstrated to those who were desirous to look at them more closely.

On the plate exhibited to the Section a few of the more important stages were figured by which the growth of the didermic blastocyst is elucidated.

It was seen that during the early stages of cleavage of the ovum there is no sensible difference in size of the cells then arising. Still, as early as the solid morula-stage, there is an unmistakable outer layer and an inner core of cells, the latter increasing from one to about a dozen cells. When the latter number is exceeded a cavity arises, the outer layer becomes the wall of this early monodermic phase, and the inner core is massed together.

With equal rapidity, however, a further differentiation of this inner core into a layer of flattened cells and a knob of more cubic ones is now inaugurated, the former arranging themselves into the inner wall of what then becomes the didermic blastocyst, the latter being at the outset a local thickening of this inner layer. The outer layer forms a closed sac over and above the inner layer and the thickened knob. The outer layer is what the author has called the trophoblast, the inner layer the hypoblast, the thickened knob containing the material out of which both the epiblast and the hypoblast that are going to contribute towards the formation of the embryo itself will be evolved.

This takes place simultaneously with a rapid extension in size of the didermic blastocyst.

The embryonic knob may be said to have a more flattened and a more convex surface; the former is applied against the trophoblast, the latter protrudes into the cavity of the blastocyst. Where these two surfaces meet, the peripheral hypoblast and the embryonic knob are connected together.

Soon, however, the convex surface of the embryonic knob is seen to be gradually converted into a cell layer, which remains in connection with the peripheral hypoblast, but which gradually becomes separated from the rest of the embryonic knob.

An expanse of cells has then been interpolated into the primitive hypoblast of the early didermic stages, in the region where the embryo is going to be evolved—*i.e.*, in the region of the embryonic shield.

As yet the epiblast is, however, not expanded into a shield, but folded together in the embryonic knob. The first indication of its expansion is a dehiscence in the central portion of the knob, by which the hemispherical knob becomes converted into a hollow cup. The upper rim of this cup at the same time becomes confluent with the trophoblast that overcaps it, the convexity of the cup becomes lessened, and the trophoblast then no longer covers the embryonic epiblast. Finally, the convexity altogether disappears, the hollow cup surface is stretched, and the flat or slightly curved embryonic shield has come into existence. The hypoblast below the embryonic shield is much less flattened than the peripheral hypoblast.

This may be called the final stage of the didermic blastocyst. It is directly comparable to the similar stage of other mammals, and somewhat more indirectly to that of the Sauropsida, with a considerable amount of food-yolk.

The formation of mesoblast, with which we will not here occupy ourselves, is very soon inaugurated.

The phenomena described above leave no doubt but that the wall of the transitory monodermic stage is epiblastic in nature, and not hypoblastic, as Robinson will have it. The true hypoblast spreads out against its inner surface, much in the same way as Van Beneden has described it for the rabbit, Van Beneden and Julin for the bat, Heape for the mole, Selenka for the opossum, and the author for the shrew. This conversion of the monodermic into a didermic stage is, however, in *Tupaja* brought about in a stage when the dimensions of the blastocyst are yet exceedingly small.

In conclusion the author pointed out that the early developmental stages here sketched have confirmed him in the conviction that in the formation of the mammalian blastocyst cænogenetic processes play a prominent part. It is by precocious segregation that cell-matter of epiblastic and of hypoblastic ancestry is arranged into a two-layered vesicle, whereas the really formative matter out of which the embryo will be built up is yet quiescent in the embryonic knob.

This fact has made the mammalian blastocyst a very puzzling structure to comparative embryologists; and we can only come to a clear conception of its real nature if we are willing to acknowledge that the holoblastic segmentation of the mammalian ovum is something totally different from the holoblastic segmentation of very many invertebrates and of Amphioxus. Being an apparently palingenetic feature, it is all the more misleading. And we must not wonder that the later processes of mesoblast formation have been affected by the cænogenetic changes just alluded to which have come about in the very early stages.

2. *On the Ancestry of the Chordata.* *By* W. GARSTANG.

3. *On the Structure of the Integument of* Polyodon.
By W. E. COLLINGE.

4. *On the Vertebræ of* Amphisile. *By* W. E. COLLINGE.

DEPARTMENT OF BOTANY.

1. *Two Irish Brown Algæ.* *By* Professor T. JOHNSON.

The author described the characters of Reinke's genus *Pogotrichum*, founded in 1892, and compared them with those of *Litosiphon*, founded in 1850 by Harvey. The recently discovered plurilocular sporangia of *Litosiphon Laminariæ*, Harv., were described, and it was considered that the evidence afforded by their position and characters with the differences in the vegetative organs was sufficient to justify the continuance of *Pogotrichum* as a genus distinct from *Litosiphon*. Lantern slides, microscopic and other illustrations, were shown.

2. *Some Chalk-forming and Chalk-destroying Algæ.*
By Professor T. JOHNSON.

The author exhibited and described the characters of a number of *Corallinaceæ* (chalk-forming red algæ) collected by him at different parts of the Irish coast during the past three years. Preparations were shown of chains of spermatia forming the antheridia in *Lithophyllum* (*Melobesia*) *lichenoides*, and attention was called to their possible mode of formation. Specimens (microscopic, &c.) of shell-boring algæ were shown and new features in their life-history and distribution described. Suggestions as to the relation of the carbonate of lime to the two groups were made and asked for.

3. *On the Development of Cystocarp in* Polisiphonia nigrescens.
By H. PHILLIPS.

4. *An Exhibition of Algæ. By* A. CHURCH.

FRIDAY, AUGUST 10.

The following Papers were read:—

1. *On the Relations of Protoplasm. By* Professor E. VAN BENEDEN.

2. *On the Periodic Variation in the Number of Chromosomes.*
By Professor E. STRASBURGER.

3. *On Chlorophyll in Animals.*
By Professor E. RAY LANKESTER, *F.R.S.*

DEPARTMENT OF ZOOLOGY.

The following Papers were read:—

1. *On the Origin and Morphological Signification of the Notochord.*
By Professor E. VAN BENEDEN.

2. *On the Carpus of the Greenland Right-whale compared with those of Fin-whales. By* Professor J. STRUTHERS, *M.D., LL.D.*

In his preliminary notice in 1885 the author stated the general conclusion that he found diminution in the number of bones in the second carpal row from *Hyperoodon* to *Mysticetus*. The following further observations relate to the whalebone whales only. The species and number dissected were: two of *Balæna mysticetus*, five of *Balænoptera musculus*, one of *B. borealis*, two of *B. rostrata*, and one of *Megaptera longimana*.

Besides noting the surface grooves, horizontal sections were made, showing the lines of fibrous suture marking off the limits of the cartilages and bringing into view ossifications not seen on the surfaces. As the fibrous sutures uniting these flat-walled cartilages are so narrow and firm as to prevent movement, these cartilages must be regarded as *individually* functionless, and we are prepared to find differences between the species and variation among individuals of the same species.

In regard to the first row of the three usual mammalian pro-carpals in *Mysticetus* the intermedium sends up a peak between the forearm bones, articulating with ulna as well as with radius, and the pisiform is widely separated from the ulnare, in both of these particulars contrasting with the finners.

In the second row, instead of the usual four disto-carpals in mammals, *Mysticetus* has but one broad cartilage bone, supporting digits III. and II., and in part digit I. Digits IV. and V. are supported by the ulnare, digit V. in part resting on the ulna, so that, on the ulnar side, the ulnare represents the entire carpus.

The *ossifications* in *Mysticetus* vary. In the 48-feet-long female, which may be reckoned adult or nearly so, the only bones ossified in the left carpus are the intermedium and ulnare, and largely so; in the right carpus an ossification occurs also in the disto-carpal, of medium size. The radiale is not ossified in either carpus. In the 35-feet-long male *Mysticetus*, in the right carpus (the left not obtained), three ossifications occur, but they are in the radiale, the intermedium, and disto-carpal, not in the ulnare. Moreover, in this two-thirds-grown *Mysticetus* the metacarpal of the pollex is fully ossified, while in the adult the pollex is entirely cartilaginous.

In the finners, in the distal row, two cartilage bones, more or less ossified, occur normally, supporting the two greatest digits. In the 65½-feet-long *B. musculus* these two are united into one bone, notches above and below and a groove on the surface indicating synostosis of two formerly separate bones. In three of the five *B. musculus* a disto-carpal was found supporting the inner of the four digits, cartilaginous in the 50-feet-long one and in the 60½-feet-long one, and with a small ossification in the 65½-feet-long one. In the 45-feet-long one there was no trace of this third disto-carpal, either bony or cartilaginous, nor was it present in the 36-feet-long *B. borealis*, nor in either of the two adolescent *B. rostrata*.

In the *Megaptera*, 40 feet long, the ulnare is a very broad bone, extending for over one-third of its breadth below the radius, thus occupying also the locality of an intermedium, and between it and the radiale occurs an undersized intermediate bone. These two latter form the entire carpus, as one row, between the radius and the massive radial metacarpal. Small ossifications occur in the radiale and in the ulnare to its ulnar side.

The *pisiform* is, in the great finners, large and square-shaped; in *B. rostrata*, narrow and directed upwards; in *Mysticetus*, transversely elongated. Regarded by some as merely a sesamoid, it serves as a stretcher, giving breadth to this broad part of the limb, steadied by the flexor carpi ulnaris muscle, which the author has found to be present in all the cetacea he has dissected, whether whalebone or toothed. In the 60½-feet-long *B. musculus* it had an ossification as large as a walnut. The pisiform may be said to be the only one of these bones adapted to serve a function. The mass of cartilage forming the carpus serves to give some low flexibility and elasticity at that part of the limb, like a piece of firm india-rubber in the middle of an oar; but the mapping into distinct cartilage bones, more or less ossified, in these whales can be explained only on the view of inheritance from some mammal whose diarthrodially jointed carpal bones were adapted to allow of particular movements.

3. *On the Species of Amphioxus.* *By* J. W. Kirkaldy.

I. *Branchiostoma Lanceolatum* (Costa).

Distribution.—Mediterranean Sea, English Channel, North Sea, Coast of Norway.
Gonads 26 pairs.
Both metapleural folds die away behind the atriopore.
Myotomes 35, 14, 12.
Snout fin of medium size, pointed.
Caudal fin lancet-shaped.

II. *Branchiostoma Californiense* (Cooper).

Distribution.—Coast of California.
Gonads 31 pairs.
Both metapleural folds die out behind the atriopore.
Myotomes 45, 17, 9.
Head region very small, snout fin not marked off from the dorsal fin.
Tail fin long and shallow.

III. *Branchiostoma Belcheri* (Gray).

Distribution.—Borneo and Torres Straits, Australia.
Gonads 25 pairs.
Both metapleural folds die out behind the atriopore.

Myotomes 37, 17, 10.
Snout fin long.
Caudal fin wide and short.

IV. *Branchiostoma Caribæum* (Sundevall).

Distribution.—East Coast of S. America, Gulf of Mexico, West Indies.
Gonads 27 pairs.
Both metapleural folds die out behind the atriopore.
Myotomes 37, 15, 8.
Snout and tail fins small.
Anus far back.

V. *Heteropleuron Bassanum.*
Branchiostoma Bassanum (Günther).

Distribution.—Bass Straits, Australia.
Gonads 30, unpaired.
Right metapleuron continuous with the caudal fin.
Left metapleuron dies away behind the atriopore.
Myotomes 44, 15, 17.
Snout fin large and pointed.
Tail fin long.

VI. *Heteropleuron Cultellum.*
Branchiostoma Cultellum (Willey).
Epigonichthys Cultellus (Peters).

Distribution.—Torres Straits, Australia.
Gonads 19, unpaired.
Right metapleuron continuous with the caudal fin.
Left metapleuron dies away behind the atriopore.
Myotomes 32, 10, 10.
Dorsal fin very high.
Anterior expansion of notochord club-shaped.

VII. *Heteropleuron Singalense.*

Distribution.—Ceylon.
Gonads 25, unpaired.
Right metapleuron continuous with the caudal fin.
Left metapleuron dies away behind the atriopore.
Myotomes 39, 17, 8.
Anus far back.
Snout and caudal fins small.

VIII. *Assymetron Lucayanum* (Andrews).

Distribution.—Bahamas.

Both metapleura meet at the anterior end of the pre-oral chamber, and are continuous with the snout fin.

Oral hood far back, and with few cirri, of which two sets, about a median cirrus, are webbed.

Gonads 29, unpaired.
Right metapleuron continuous with the caudal fin.
Left metapleuron dies away behind the atriopore.
Myotomes 44, 9, 13.
Long caudal extension.

DEPARTMENT OF BOTANY.

The following Papers were read:—

1. *On the Phylogenetic Position of the Chalazogamic Amentiferæ.*
By Miss M. BENSON.

The author reviewed the points of resemblance that obtained between the Cupuliferæ and the four chalazogamic genera, Alnus, Betula, Corylus, and Carpinus, and was led to the conclusion that, with the exception of the difference in the route of the pollen tube and the concomitant adaptations, no fundamental distinctions could be drawn between the chalazogamic and porogamic genera.

The author also described and exhibited some abnormal inflorescences of *Fagus sylvatica*, *Quercus Ilex*, and *Alnus glutinosa*, and suggested atavism as their explanation.

2. *On the Hygroscopic Dispersal of Fruits in certain Labiates.*
By Miss D. PERTZ.

3. *On the Hybridisation of Orchids.* *By* Dr. JAMES CLARK.

SATURDAY, AUGUST 11.

DEPARTMENT OF ZOOLOGY.

The following Reports and Papers were read:—

1. *Interim Report on a Digest of the Observations on the Migration of Birds at Lighthouses.*—See Reports, p. 348.

2. *Report on the Legislative Protection of Wild Birds' Eggs.* See Reports, p. 347.

3. *Report on a Deep-sea Tow Net.*

4. *On Temperature as a Factor in the Distribution of Marine Animals.*
By Dr. O. MAAS.

In the question of the influence of temperature on marine animals no sufficient distinction has been made hitherto between three classes of facts:—

1. Between the animals of the Plankton, the Benthos, and the Nekton.
2. Between the vertical and the horizontal differences of temperature.
3. Between eurythermal animals which can stand great differences of temperatures, and the eurythermal ones which cannot.

The eurythermal animals cannot be appealed to in proof of anything regarding temperature.

For the stenothermal the average temperature of a locality is of small zoogeographical value, while the extent of variation is the most important factor.

The Nekton animals are more eurythermal; otherwise their power of swimming, which brings them into very different conditions of temperature, would be of no use to them.

The Plankton and Benthos animals are (with some exceptions discussed) more stenothermal; hence results the known division of the coasts.

A distribution of the animals of the open ocean into regions is possible too, chiefly on account of the currents.

Some instances of that were given from the facts of the Plankton expedition, chiefly of the Medusæ, which have been worked out by Dr. Maas. Most interesting in this regard are the *Geryonids, which in every ocean basin do not exceed a certain N. or S. latitude, and which as Plankton animals occupy a similar portion of the map as the corals of the Benthos.*

Dr. Maas is led to the conclusion that a comparison between the vertical differences and those found in higher latitudes can only be carried to a limited depth.

The horizontal distribution of the pelagic fauna is not compensated by the vertical differences.

There are no various belts of vertical life; the intermediate fauna between the Plankton of the surface and the Benthos of the abyss may be supposed to be only Nekton.

This is valid for the deep sea. In lower seas the life may be continuous from the surface to the bottom. Sometimes special conditions, especially of temperature, prevail (*e.g.*, in the Mediterranean, where a depth of 2,000 m. shows 13°). The occurrence of a deep-sea pelagic fauna, neither belonging to the surface nor in connection with the ground, as well as the survival of deep-sea animals coming to the surface, may be explained by this higher temperature.

5. *Second Report on the Zoology of the Irish Sea.*

See Reports, p. 318.

6. *On Marine Fish-hatching and the Dunbar Establishment of the Fishery Board for Scotland.* *By* Professor W. C. McIntosh, *F.R.S.*

It was stated that we are yet in doubt as to the beneficial effects to the fisheries of the artificial hatching of sea-fishes, but that the importance of the issue demanded a thorough trial. Several nations, such as the Americans and Norwegians, had chiefly experimented with the cod, other forms having been dealt with in small numbers. Though the sole was selected as the most suitable species, the lateness of its spawning period gave an opportunity for a preliminary series of experiments with the plaice. Accordingly a total of 396 plaice were collected, the average size of the males being about 17 inches, and that of the females about 20 inches. From these 27,350,000 ova were obtained, hatched in the boxes (Dannevig's), and the larval plaice—to the number of 26,060,000—sent into the sea, the loss in the process being only about 4·4 per cent.

At Dunbar the eggs are shed in the spawning-pond, and carried to the spawn-collector by the current. They are then counted and placed in the hatching-boxes. The sea-water for these is passed through a series of flannel-filters, so as to secure purity. Moreover, besides the current entering the end of the box, an up-and-down movement is communicated to them twice every minute, so that the ova are evenly distributed through the water. On the whole the operations for the first year were most successful.[1]

DEPARTMENT OF BOTANY.

The following Papers were read:—

1. *On the Correlation between Root and Shoot.* *By* Professor L. Kny.

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[1] A full account of the experiments will be given by Dr. Fulton in the forthcoming *Twelfth Annual Report of the Fishery Board for Scotland.*

2. *On the Sensitiveness of the Root-tip.* *By* Professor W. Pfeffer.

3. *Exhibition of Diagrams.* *By* Professor L. Kny.

MONDAY, AUGUST 13.

Department of Zoology.

The following Report and Papers were read:—

1. *Interim Report on Telegony.*—See Reports, p. 346.

2. *On some Difficulties of Darwinism.*
By Professor D'Arcy Thompson.

3. *On Social Insects and Evolution.* *By Professor* C. V. Riley.

Experiment and discussion on the question as to whether acquired characters are transmitted or not through heredity have of late been largely based upon the economies of insects, and especially of the social species. The author gives a summary of what is known of the habits and economies of bees, wasps, ants, and termites, especially as to the development of the young. He points out that the origin of neuters, with their diversified forms, in these social insects has been considered one of the greatest difficulties with which the theory of natural selection has had to contend. Weismann, in urging his own particular theories to account for the variation which organisms have undergone, insists, and has, within the last year, in his controversy with Herbert Spencer, emphasised his belief, that these neuter insects absolutely preclude the idea of the transmission of acquired characters. The author believes, on the contrary, and endeavours to show, that while these neuters among social insects, with their varied structures and habits, do indeed offer serious obstacles to the theory of natural selection as an all-sufficient theory to explain the phenomena, these are nevertheless perfectly explicable upon the general principles that have governed the modification of organisms, among which natural selection plays an important but limited part.

Among the social Hymenoptera, where, as in the bees and wasps, the larva is nursed and brought up in a definite cell or cradle, the three castes of male (or drone), fertile female (or queen), and neuter (or worker) are quite definitely fixed and separated. The differences between the worker and the queen are, however, solely due to the treatment of the larvæ, and are consequently under the control of the colony. The same larva, according to treatment and nurture, may produce either a perfect queen or a worker, between which the differences as to size, structure, external and internal organisation, and length of life are very great. This is absolutely and definitely proved for the bees, and is doubtless equally true, though with less absolute proof, of the wasps, in which the same three castes of male, female, and neuter obtain in some species, while in others the neuters are replaced by parthogenetic or unimpregnated females, normally capable of reproducing. In the ants, where the larva is not confined to a definite cradle, and where there are, in the more typical species, two castes of neuters, viz., soldiers and workers, the variation between the different castes is greater, and there is also more variation in the individuals composing the different castes; but the evidence all points to the fact that these different individuals are also the result of food and nurture, very much as with the bees and wasps.

In the three families of social Hymenoptera above mentioned the young are maggot-like and absolutely helpless and dependent on the nurses. In the termites, which belong to a different order (Platyptera), much older in time according to the palæontological record—an order in which the young are born in the image of the parent and are more or less independent from birth—one would expect to find larval nurture and environment less potent in influencing ultimate structure. Yet all the facts known, and particularly the late most painstaking observations and experiments of Grassi, prove conclusively that here, also, the young are dependent upon the nurses, and, more remarkable still, may be diverted, according to the food and treatment given, to any of the four castes which characterise the typical termite colony, there being, in addition to the male and female, two kinds of neuters, viz., soldiers and workers, as in the true ants. In the first larval stage, or when first hatched, the individuals are, to all appearances, absolutely alike, and each possesses the potentiality of becoming either a worker, or a soldier, or a perfect sexed individual. Nay, further, the pupæ, or nymphs, may be diverted into reproductive forms which never acquire wings and which are called supplementary queens and kings; and even larvæ may be so diverted into reproductive forms, with no further external structural development, when they become complementary or neotinic kings and queens.

The steps in the development from the simpler to the more special structures and attributes belonging to the species with the most perfect social organisation may be traced in the different species and genera of their respective families in all social insects of the present day. The amount of variation is often great in the ants and termites, where the environment is less fixed than in the bees and wasps, and this variation, among termites, is particularly manifest in the economy of the same species, as exemplified in *Eutermes*, which the author has studied in the West Indies, and in which the number of queens varies from one to nine or more. It is not generally known, but it is a fact, that existing termites (using the term in the broader sense, so as to include several genera) exemplify all the steps in development from species which are active in broad daylight (the neuters having faceted eyes and dark integument, and, so far as is known, no definite nest or termitary), to the more specialised species in which the economy and division of labour are most perfect, and in which the neuters and soldiers are blind and always work in the dark and build elaborate structures. Further, the neuters in termites are truly without sex or are modified individuals which might have produced either sex; while in the Hymenoptera they are invariably modified females.

In so far as these different forms of neuter insects depend for their development on the food and treatment given by the nurses, they are outside the domain of natural selection. The author believes, however, that there is a potential, inherited tendency in the young larva to develop in the various directions that have been fixed for each species in its past development, as he cannot believe, *e.g.*, that young larvæ taken from one species of termites, and brought up under the care of the nurses of any other species, can be diverted to the forms peculiar to this last. There is a possibility, since the food of these young in the social insects consists largely of secretions from the nurses, that these secretions may so influence the changes as to confine them to the specific forms of its own species, regardless of the parentage of the young. That there can be any such powerful influence of nurture as would neutralise and overcome the inherited tendencies of species is, however, extremely improbable: its bare possibility opens up a most interesting field for experiment, which is easily made, and doubtless soon will be made.

The author believes, with Darwin, that the variations in social insects have been guided by natural selection among colonies, but that there has also been what he calls social selection among individuals. Competition has been between colonies rather than individuals, and those colonies which have acquired, through heredity, the habit of producing, from one or more fertile females, the different castes characteristic of the species have, in course of time, survived. He believes, however, that this colony-selection, as well as the social selection among individuals, has been not only along lines that were and are useful to the species, but along lines of secondary utility, and even along lines which are purely fortuitous and still most variable and unfixed.

Finally, as between Weismann's views and those held by Darwin himself, the author feels that the facts furnished by the social insects strongly favour the transmission, through heredity, of acquired characters, both psychic and structural, but that they also require other factors besides that of natural selection to explain them.

The trouble with all theories of reproduction and heredity based solely on embryologic and microscopic methods is, that the essence, the life principle, the potential factors, must always escape such methods. Any theory that will hold must cover the psychical as well as the physical facts—the total of well-established experience—and this truth was recognised by Darwin in framing his tentative theory of pangenesis. We are all in these matters simply discussing processes, and the author believes that too much has been made of the cell theory, the cell being but the medium through which assimilation, growth, organisation, regeneration, and reproduction are effected by the ultimate elements and the inherited potential forces, call them what we may. The idea that the individual during its lifetime develops all that is potential in the germ seems to him more philosophic than the idea that the germ originates, at a specific moment of time, the tendency to all that develops in the individual. It may be a perfectly correct conception, to use Weismann's language, that the primary constituents for the characters of the different forms of social insects are included in the egg, and that a particular form of stimulus decides as to which group shall undergo development; but it is difficult to believe, in the light of the facts which are known concerning social insects, that the different kinds of ids and determinants which are thus conceived to characterise the germ have not been impressed upon it as a consequence of the characters, both acquired and congenital, of the parents.

The author finally calls attention to the significant fact that just as in man, among Mammalia, the higher intellectual development and social organisation are found correlated with the longest period of dependent infancy; that this helpless infancy has been, in fact, a prime influence in the development, through family, clan, tribe, and state, of our highest organisation and civilisation; so in the insect world we find the same correlation between the highest intelligence and dependent infancy, and are justified in concluding that the latter is, in the social insects as in man, in the same way a prime cause of the high organisation and division of labour so characteristic of them.

4. *On the Rôle of Sex in Evolution. By* JOHN BERRY HAYCRAFT, *M.D., Professor of Physiology, University College, Cardiff.*

While Weismann admits that the power to vary is a property of protoplasm, he looks upon sexual conjugation as a means whereby the number of these variations may be increased. But we find that the power to vary is itself a most varying character of protoplasm, for both in the case of sexual and asexual reproduction certain species constantly produce striking varieties, while others rarely produce them. We can therefore state, not only that variation is a quality of protoplasm, but that it has and can acquire this quality in varying degree and apart from sexual congregation; moreover, greater varieties in the progeny can be obtained simply by increasing the number of the offspring. It would appear therefore that, if we accept the view held by Weismann, we must assign to sexual conjugation a function already possessed by protoplasm, and it is difficult to understand its utility. If, however, we remember that the varieties which occur in newly allied forms (the only ones which conjugate) are variations chiefly in quantity (differences in size of the whole or parts, amount of pigment, &c.), we can hardly doubt the generally accepted and more popular view, that the children tend to the mean of their parents; a view supported by Galton's admirable researches. If this be true sexual conjugation tends to diminish variations, and the author suggests that this is indeed the *rôle* of sex in evolution. Our attention has been so much engrossed with the changes of the environment, and with the consequent production and establishment of new varieties, that we have perhaps considered too little the fact that often for long periods of time the environment may remain stationary, and that under these conditions existing types must remain stable. The persistently preserved types in our inland ponds and lakes, types such as the housefly and cockroach, which for ages have remained the same, illustrate this stability. Living matter must therefore be capable both of the power to vary and of stability; the first it possesses, the second it gains by sexual conjugation, which tends to prevent the slight deviations of a form which has become adapted to its environment from producing still further deviation by blending them together so that some, at any rate, of their progeny may preserve the useful ancestral qualities. To sex we owe our fairly defined species and genera; without sex we cannot doubt that life would exist in the form of innumerable varieties that we should fail to group together.

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5. *On the Relation of Mimetic Characters to the Original Form.*
By F. A. DIXEY, *M.A., M.D., Fellow of Wadham College, Oxford.*

An objection that has been often brought against the theory of mimicry, as enunciated by Bates and accepted by Darwin, is the difficulty of imagining the first stages in the production of a mimetic pattern. Fritz Müller[1] endeavoured to meet this objection by alleging that mimicry chiefly originated between forms that already bore considerable resemblance to each other. The main instance (that of *Leptalis melia*) on which he relied in order to prove his point was not well chosen, for there is reason to think that he was in error both in considering that it represented the ancestral form of *Leptalis* and in supposing that it was not protected by mimicry. Nevertheless, his contention is sound in so far as it emphasises the fact that the process of mimetic assimilation depends rather on the development of old than on the starting of new features.

An illustration of this principle is afforded by a comparison of the non-mimetic butterflies *Pieris locusta* and *P. thaloe* with the mimetic species of the closely allied genus *Mylothris*, and with *Heliconius numata*, which serves as the model for the latter; all these forms inhabiting the same part of the neotropical region. An almost perfect transition can be traced on the undersides from the non-mimetic species of *Pieris*, through *M. lypera* ♂, *M. lorena* ♂, *M. pyrrha* ♂, *M. lorena* ♀, to *M. pyrrha* ♀, this last butterfly being a very close copy of *Heliconius numata*. The whole series shows (1) that a practically perfect mimetic pattern can be evolved by gradual and easy stages without any violence or abruptness of change; (2) that it is not necessary that the forms between which mimicry originates should possess considerable initial resemblance; (3) that so small a beginning as the basal red patches on the underside of the hind-wing of many Pierines gives sufficient material for the assimilative process to work on.

The feebler development of the mimetic pattern in the males of this group calls for some explanation. No doubt the females require more protection, but does there exist any active check on the fuller assumption of mimetic patterns by the males? The retention of the original white by the latter sex has been in similar instances attributed to female choice; Mr. Wallace, on the other hand, thinks it due to the difference of habits in the two sexes, the females alone flying in company with the mimicked *Heliconii*. But this leaves unexplained the presence of a partial mimetic pattern in the male. The probability is that, although on the wing it may be advantageous rather than otherwise to the male, as Mr. Wallace thinks, to be taken for an ordinary white butterfly, yet when the insect is at rest and settled with the wings erect, any Heliconine resemblance would be to some extent protective; and the whole aspect of these males, the underside alone of which shows any mimetic features, is the resultant of these two divergent tendencies. The mimetic features of the male cannot be regarded as a mere incidental result of the more complete transformation of the female, because in many species of other groups the female is completely mimetic while the male shows no approach whatever to a mimetic change; moreover, there is a species of *Hesperocharis* (*H. hirlanda*) in which not only the male but both sexes show a partial mimetic pattern no further advanced than that of *M. lorena* ♂ or *M. pyrrha* ♂. It is difficult to believe that in this case the pattern is not in some degree protective.

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[1] *Jenaisch. Zeitschr.*, vol. x.

Red basal spots like those of the mimicking Pierines are in some cases found in the mimicked *Heliconii:* this is especially the case in those that form models for the Pierine genera *Euterpe* and *Pereute.* These spots are too widespread in the Pierine sub-family to have arisen from imitation of the *Heliconii;* their presence in the latter is probably due to 'reciprocal mimicry' between distasteful forms, as suggested by the author in 'Trans. Ent. Soc. Lond.,' 1894, p. 298.

A curious case of a mimetic group is afforded by the Pierines *Euterpe critias* and *E. bellona,* together with their respective models *Papilio zacynthus* and the *Heliconii* of the *thelxiope* group. The *Papilio* and the *Heliconii* have no close resemblance to each other, but appear to be held together, as it were, by the intermediate Pierines. If the *Heliconii* are considered as the models for the whole group, the question arises why *E. critias* should copy a mimic, and not a very good one, instead of the original distasteful model. It is more probable that here also we have an instance of an 'inedible association;' this conclusion being strengthened by the fact that a certain amount of 'give and take,' or 'reciprocal mimicry,' seems to have occurred between the Pierines and the *Papilio.*

The paper was illustrated by coloured drawings of the species referred to.

6. *On Certain Principles of Progressively Adaptive Variation Observed in Fossil Series. By* Professor H. F. OSBORN.

7. *On the Wing of Archæopteryx Viewed in the Light of that of Some Modern Birds. By* W. P. PYCRAFT.

In this paper the author contended that certain of the Galliformes, such as the common fowl and turkey for instance, are descended from an ancestral form of a strictly arboreal habit, in which the pollex and index digits were armed with claws to assist in climbing as well as to save itself from falling. These claws remained functional until a sufficient number of the primary (and secondary) remiges had developed to convert the wing into an organ of flight. Until this was effected, the development of these remiges nearest the wing (Nos. 8, 9, 10) was arrested, so that the tip of the index digit might be left free for grasping. The arrested development of the remiges referred to is the only clue we have left at the present day, the claw of the second digit having been lost, whilst that and the pollex are very small. These deductions were drawn from a precisely similar arrangement shown by the author to exist in *Opisthocomus cristatus,* a bird which shows many other unmistakably primitive characters.

It was also pointed out that there is reason for believing that the claws of Archæopteryx were of prime importance only during a similar period of life—the nestling period. A restoration in the shape of a model of the wing of Archæopteryx was exhibited, in which it was shown that the remiges rested upon the third digit, so as to leave the tip of the second free in a manner more or less resembling the nestling condition of *Opisthocomus.* It was, however, pointed out by the author that this digit might have supported the semiplume-like feathers seen in the fossil, overlying the quill feathers. These may have possibly extended to the tip of the second digit, and represented what we know as 'major' coverts.

8. *On the Nephridial Duct of* Owenia. *By* Professor G. GILSON, *of Louvain.*

Owenia is a tubicolous annelid discovered by Delle Chiaje in the Gulf of Naples, and especially studied by Claparède. The latest writer on its anatomy, Dr. von Drasche, confesses his ignorance as to the presence or absence of the nephridia, as well as to the way through which the genital products are led out of the cœlom.

Although my own researches are far from terminated, I am able to give some information on the subject.

In fact, the nephridial system is not altogether absent, but is in a state of extreme reduction and seems to have lost all secretory function. It consists usually of one pair, sometimes two pairs, of very small funnels, lying in the posterior part of the sixth segment, against the muscular layer, in an extremely dorsal position.

Each of these funnels ends in a very thin tube, which passes through the muscular coat; but, instead of opening directly and freely on the epidermic surface, these tubes fall into a longitudinal duct which runs forward and opens, through a tiny pore, at the other end of the sixth segment.

This duct is a merely epithelial structure; it lies outside of the thick basal membrane, within the epiderm itself. Being thus superficially situated, it is exteriorly visible, and appears as a very sinuous line, extending the whole length of the sixth segment Dr. von Drasche, in his valuable monograph, very accurately represented this line, though he did not make out its significance.

I have seen this epithelial duct opening at certain places, thus taking the shape of a groove instead of that of a tube. These occasional imperfections of its structure, together with the peculiar disposition of its constituent cells, show that this canal originates as a longitudinal folding of the epithelium. They lead us also to consider it as an organ still in full course of phylogenetic evolution. Its utility, as well as the original cause of its formation, is obvious. I have shown elsewhere that the sandy tube in which the *Owenia* lives is rather tight round the fore end of the body. The genital products could scarcely reach the exterior were they directly ejected into the space between the worm and its protective sheath. The animal is obliged to protrude its body out of its dwelling, but, thanks to the epidermic canal, it is spared the trouble and danger of laying bare more than its five anterior segments, though the funnels lie in the posterior part of the sixth.

A question now presents itself: What is the morphological significance of this epidermic duct?

It is not my intention, in the present state of my researches, to enter into a full discussion of the subject. I shall content myself with calling attention to the bearing which the discovery of the epidermic canal of *Owenia* may have on the discussion of the homologies of the excretory system in general.

We know other instances of a longitudinal duct in connection with the nephridia. The most classical one is that of *Lanice conchilega,* described by Mr. Cunningham and Dr. E. Meyer.

The longitudinal duct of this species is generally regarded as an unsegmented part of the longitudinal row of cells which gives origin to the excretory system—an opinion which I have no reason to oppose.

But certain morphologists go further than that, and compare the longitudinal duct of *Lanice, Polymmia, Polygordius,* and others to the segmental canal or primitive ureter of vertebrates. Professor Wilson, in his remarkable paper on the germ-bands of *Lumbricus,* goes even so far as to consider this homology as *evident.*

On this point I venture to recall attention to Professor Haddon's hypothesis as to the phylogenetic origin and epiblastic nature of the segmental duct of vertebrates.

The existence of such an evidently adaptive structure as the epidermic duct of *Owenia* seems to give a remarkable confirmation to his suggestion as to how a continuous groove into which the nephridia opened may have been converted into a canal.

It is not evident at all that the segmental duct really is, in its whole length, an unsegmented part of a cell-row homologous to that of *Clepsine* or *Lumbricus.* It may have appeared at a much later period of the phylogenetic evolution, and have been, at a given moment, a new structure corresponding to new wants, just as the epidermic duct of *Owenia* corresponds to a peculiar disposition of the protective tube of the worm. The coexistence of a segmental duct analogous to the epithelial duct of *Owenia,* and of a structure homologous to the longitudinal canal of *Lanice,* is even possible.

I do not affirm that the epidermic duct of *Owenia* really represents the segmental duct at an early stage of its phylogenetic development. I rather think that we have here a case of homoplasy, not of homogeny. But I believe that the homology of the primitive ureter is not a settled question, as the American professor would have it, but that it remains a question open to further investigation.

DEPARTMENT OF BOTANY.

The following Papers were read:—

1. *On the Origin of the Sexual Organs of the Pteridophytes.*
By Professor DOUGLAS H. CAMPBELL.

While the close affinity of the *Bryophytes* and *Pteridophytes* has been long recognised in the origin and early divisions of the sexual organs, there exist differences that have been looked upon as radical. This is especially noticeable in the archegonium.

A comparison of the structure and development of the sexual organs of the higher hepatics (Anthocerotiæ) with those of the Eusporangiate Pteridophytes, *i.e.*, Ophioglosseæ, Marattiaceæ, Equisetineæ, and Lycopodineæ, shows remarkable points of resemblance, enough to warrant the hypothesis that here is to be sought the connection between the Bryophytes and Pteridophytes.

2. *Notes upon the Germination of the Spores of the Ophioglosseæ.*
By Professor DOUGLAS H. CAMPBELL.

The gametophytic stage of these plants is very imperfectly known, and hitherto only the very advanced conditions in two species.

The author succeeded in germinating two other species—*Ophioglossum* (*Ophioderma*) *pendulum* and *Botrychium virginicum.* In both the first division of the spore occurs before any chlorophyll is formed.

The author also found old prothallia of *B. virginicum* with young plants attached, but too far advanced to study the development of the reproductive organs and embryo.

3. *On Sterilisation and a Theory of the Strobilus.*
By Professor F. O. BOWER, *F.R.S.*

In submitting a theory of the strobilus to Section D it is assumed that Hofmeister's general conclusions will be accepted, that antithetic alternation was constant throughout the evolution of archegoniate plants, and that the sporophyte has been the result of elaboration of the zygote. The main points of the theory may be briefly stated as follows:—

1. Spore-production was the first office of the sporophyte: its spore-bearing parts are to be regarded as primary, its vegetative parts as secondary in point of evolutionary history.
2. Other things being equal, increase in number of carpospores is an advantage. A climax of numerical spore-production was attained in homosporous vascular cryptogams.
3. Sterilisation of potential sporogenous tissue has been and is a widespread phenomenon, appearing as a natural consequence of increased spore-production.
4. Parts of the sterile tissue appeared as septa, partitioning off the remaining sporogenous tissue into separate loculi.
5. Septation to form synangia and subsequent separation of the sporangia are phenomena illustrated in the upward development of vascular plants.

6. Such septation may have taken place repeatedly in the same line of descent.

7. The sporogonial head as a whole is the correlative of the strobilus or flower, and the apex of the one corresponds to the apex of the other.

8. The progression from the one to the other depended upon (*a*) septation by formation of sterile partitions, (*b*) eruption of the surface to form appendicular organs upon which the sporangia are supported (sporangiophores, sporophylls).

9. The sporophylls, originally small and of simple form, were in the course of descent susceptible of great increase in size and complexity of form.

10. In certain cases foliage leaves were derived from sterilisation of sporophylls.

4. *On a Method of Taking Casts of the Interiors of Flowers.*
By Miss N. F. LAYARD.

5. *On the Function of the Nucleus.* *By* Professor E. ZACHARIAS.

6. *Exhibition of Diagrams.* *By* Professor LÉO ERRERA.

TUESDAY, AUGUST 14.

DEPARTMENT OF ZOOLOGY.

The following Papers were read:—

1. *On the Blood of* Magelona. *By* W. B. BENHAM, *D.Sc.*

The blood of this annelid differs entirely from that of any other chætopod hitherto examined. Instead of a red (hæmoglobinous) liquid plasma, in which float a few nucleated (colourless) corpuscles, or free nuclei, the blood-vessels of *Magelona* are completely filled with very small spherical globules of a madder-pink colour, floating in an extremely small amount of colourless plasma. These globules are not cells; there are free nuclei scattered amongst them, but the coloured globules are not nucleated. The colour of the globules is due to a pigment similar to hæmerythrin; the globules themselves, when shed, exhibit a marked tendency to run together like oil-drops and fuse with one another. This peculiar and rather viscous mass seems to be intermediate, in some respects, between the absolutely liquid, coloured plasma of chætopods generally and the red corpuscles of mammals, which float in a comparatively small amount of colourless plasma; further, the globules in *Magelona* probably originate, as those of mammals do, within cells, from which they are released.

2. *Suggestions for a New Classification of the* Polychæta.
By W. B. BENHAM, *D.Sc.*

The *Polychæta* may be divided into two grades—(*a*) the *Eucephala*, in which the prostomium retains its original condition as a lobe overhanging the mouth, and the peristomium shows no tendency to overgrow it. The body segments are all alike. The second grade (*b*) may be called *Cryptocephala*, as the peristomium grows forward and fuses with, or even entirely conceals, the prostomium, which is greatly reduced. The body segments are differentiated into two groups, indicated externally by the sudden alteration of the chætæ, and internally by certain differences.

The *Eucephala* includes four sub-orders:—

Sub-order 1. The *Nereidiformia* (= *Errantia*, auct.) together with *Ariciidæ*.—In this group, with a few exceptions, the prostomium carries tentacles and palps, and the peristomium usually carries special cirri. The parapodia are well-developed lobes, supported by strong acicula. The chætæ are jointed (gomphotrichs) or unjointed (holotrichs); no uncini occur. A pharynx exists, which frequently is armed with jaws. There are other characters drawn from internal organs.

Sub-order 2. *Scoleciformia* includes the four families—*Opheliidæ*, *Arenicolidæ*, *Scalibregmidæ*, and *Maldanidæ*.

The prostomium does not carry tentacles or palps, the peristomium is without special cirri. The parapodia are but feebly developed knobs or ridges, and are not supported by acicula. The chætæ are holotrichs. Sensory processes feebly developed or absent. Internally the most marked feature is the diminution in number of the nephridia connected with the incomplete character of the septa. There are no jaws, though the anterior end of the gut may be eversible.

Sub-order 3. *Terebelliformia* (Families.—*Cirratulidæ*, *Chlorhæmidæ*, *Sternaspidæ*, *Terebellidæ*, &c.).—The prostomium carries tentacular appendages (the branchial processes of *Chlorhæmidæ*). The achætous peristomium may carry filamentous processes. Parapodia, mere ridges or knobs; no acicula; chætæ are holotrichs and uncini. Dorsal cirri may be present on a few of the anterior segments, and they function as gills. Buccal region not eversible. Internally the nephridia present a dimorphism, accompanied in many cases by reduction in number.

Sub-order 4. *Capitelliformia* includes the family *Capitellidæ*.

The second grade, *Cryptocephala*, is divided into two sub-orders:—

Sub-order 1. *Spioniformia* (Families—*Spionidæ*, *Magelonidæ*, *Chætopteridæ*, *Ammocharidæ*) retains the prostomium as a small lobe, without definite tentacles or palps, but the peristomium is relatively large, and extends forwards on either side of the prostomium; this segment usually carries very long flexible tentacles. The parapodia are only feebly developed and incomplete; no acicula; the chætæ holotrichs; uncini may occur. Dorsal cirri, if present, become branchial organs. Buccal region eversible, but without jaws. Nephridia but imperfectly known.

Sub-order 2. *Sabelliformia* (*Sabellidæ*, *Eriographidæ*, *Serpulidæ Hermellidæ*). The prostomium is in most cases entirely concealed by the great development of the peristomium, and may be reduced to mere sensory knobs. But the palps are very greatly developed and function as gills. Parapodia only slightly projecting, or mere ridges; chætæ holotrichs and uncini. Dorsal cirri, if present, are branchial, or modified to form a thoracic membrane. Nephridia dimorphic—the anterior pair large, opening by a median dorsal pore on the first segment. The remainder act as genital ducts.

3. *On Museum Preparations.* *By* E. S. GOODRICH.

4. *On Random Publishing and Rules of Priority.*
By THOMAS R. R. STEBBING, *M.A.*

Modern zoology is a study of continually extending scope. The literature is vast, costly, and polyglot. The channels of publication are so innumerable that naturalists can scarcely tell which way to turn. In books, in magazines, in reports of learned societies, the information required by one set of students is often so combined with that required by several other sets that the expense of obtaining it becomes prohibitory. The proposal is hazarded that the leading societies should set an example by arranging among themselves for a division of labour, in the hope that by degrees scientific workers might be induced to issue their new discoveries from a few well-recognised centres, instead of insisting on the present liberty of ubiquitous publication. A Committee of the British Association, it is suggested, might usefully undertake a preliminary consideration of what is possible or expedient in this respect; and, while ventilating the larger subject, might also propose a settlement of some debated questions of zoological nomenclature. A special proposal put forward is, that for every country there shall be a single authorised journal to receive the names of new genera and species, with brief descriptions appended; all claims to priority being dependent on the date of this record.

5. *On the Relations of the Cranial Nerves to the Sensory Canal System of Fishes.* *By* W. E. COLLINGE.

6. *On some Models of the Crania of Siluroids.* *By* H. B. POLLARD.

7. *On the Epidermis of the Plantar Surface and the Question of Use-Inheritance.* *By* F. A. DIXEY, *M.D., Fellow of Wadham College, Oxford.*

It is well known that in the human adult the skin of the sole of the foot is thickened as compared with that of the dorsum, and it is also known that this local thickening on the plantar surface is present before birth. It is therefore not the direct result of the use of the sole in walking, though it might possibly be held to be due to use-inheritance. But in addition to the general plantar thickening, there is also known to exist a special thickening, in the adult, of the skin covering the heel and toe-ball, which is no doubt correlated with the heel-and-toe gait specially characteristic of man. It was suggested by the late Professor Romanes that it would be of importance to ascertain the time of appearance of this special as distinct from the general plantar thickening, inasmuch as its appearance before birth, should that be proved to occur, would seem to be more easily accounted for on the principle of use-inheritance than on that of pure natural selection. The general plantar thickening in the embryo might be held to be simply representative of the condition in a prehuman ancestor; not so, however, the special thickening of the heel and toe-ball. Six embryos, whose ages varied from about the third to the ninth month, were examined in concert with Professor Romanes. As the inner limit of the corium is in most cases not exactly determinable, the epidermis alone was measured, and the results were as follows:—(1) The general plantar thickening had begun in the earliest embryo examined. (2) The special thickening of the toe-ball had also begun at the same age. (3) The special thickening of the heel was not discoverable in any one of the specimens, which ranged up to the time just preceding birth. These results were unexpected, for it had been anticipated that both the special thickenings would have been found in the embryo to be either absent or present together, and at first sight it seemed as if no light were thrown by the observed facts on the question at issue. On further consideration, however, and after special study of the gait of the lower primates, it appeared to the author that the thickened epidermis of the toe-ball in the embryo simply represented an ancestral condition when the gait resembled that of most monkeys, who walk, as a rule, with the heel raised from the ground, only using the whole length of the sole when resting or squatting. The phenomenon would, therefore, seem to admit of a far more easy explanation under the theory of natural selection pure and simple than under that of use-inheritance.

DEPARTMENT OF BOTANY.

1. *On Pachytheca.* *By* G. MURRAY.

2. *On the Structure of Fossil Plants in its bearing on Modern Botanical Questions.* *By* Dr. D. H. SCOTT, *F.R.S.*

3. *A Thames Bacillus.* *By* Professor MARSHALL WARD, *F.R.S.*

4. *On the Influence of Light on Diastase.* *By* Professor J. R. GREEN.

5. *A Contribution to the Geological History of Cycads.* *By* A. C. SEWARD.

SECTION E.—GEOGRAPHY.

PRESIDENT OF THE SECTION—Captain W. J. L. WHARTON, R.N., F.R.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

YOU will not be surprised if, having called upon an hydrographer to preside over this Section, he takes for the subject of his review the Sea. Less apparently interesting, by reason of the uniformity of its surface, than the land which raises itself above the level of the waters, and with which the term geography is more generally associated, the ocean has, nevertheless, received much attention of late years. In Great Britain, especially, which has so long rested its position among the nations upon the wealth which our merchant fleets bring to its shores, and upon the facilities which the sea affords for communication with our numerous possessions all over the globe, investigation into the mysteries, whether of its ever-moving surface or of its more hidden depths, has been particularly fascinating. I purpose, therefore, to attempt a brief survey of our present knowledge of its physical condition.

The very bulk of the ocean, as compared with that of the visible land, gives it an importance which is possessed by no other feature on the surface of our planet. Mr. John Murray, after a laborious computation, has shown that its cubical extent is probably about fourteen times that of the dry land. This statement appeals strongly to the imagination, and forms, perhaps, the most powerful argument in favour of the view, steadily gaining ground, that the great oceans have in the main existed in the form in which we now see them since the constituents of the earth settled down into their present condition.

When it is considered that the whole of the dry land would only fill up one-third of the Atlantic Ocean, the enormous disproportion of the two great divisions of land and sea becomes very apparent.

The most obvious phenomenon of the ocean is the constant horizontal movement of its surface waters, which in many parts take well-defined directions. These great ocean currents have now been studied for many years, and our knowledge of them is approaching a point beyond which it is doubtful whether we shall ever much advance, except in small details. For though, while indisputably the waters continually move in each great area in generally the same direction, the velocities vary, the limits of the different streams and drifts vary, mainly from the ever-varying force and direction of the winds.

After long hesitation and much argument, I think it may be now safely held that the prime motor of the surface currents is the wind. Not, by any means, the wind that may blow, and even persistently blow, over the portion of water that is moving, more or less rapidly, in any direction, but the great winds which blow generally from the same general quarter over vast areas. These, combined with deflection from the land, settle the main surface circulation.

I do not know if any of my hearers may have seen a very remarkable model, devised by Mr. Clayden, in which water disposed over an area shaped like the Atlantic, and sprinkled over with lycopodium dust to make movement apparent, was subjected to air impelled from various nozzles, representing the mean directions of the permanent winds. It dispelled the last doubt I held on the subject, as not only were the main currents reproduced, but the smaller effects and peculiarities of the Atlantic drifts were produced with surprising accuracy.

There is a small current, long shown on our charts, but which I had always regarded with suspicion. I refer to the stream which, after travelling from the Arctic Ocean southward along the east coast of Greenland, turns sharply round Cape Farewell to the northward into Davis Straits, where it again doubles sharply on itself to the southward. This is exhibited, in the model, in all its details, and is evidently caused by the pressure of the water forced by the mimic Gulf Stream into the Arctic region, where it has no escape except by this route, and is pressed against the land, round which it turns as soon as it can. This is, no doubt, the explanation of the real current.

The very remarkable winter equatorial current, which runs in a narrow belt eastwards, just north of the main stream travelling west, was also reproduced with extraordinary fidelity.

The winds, however, that are ordinarily considered permanent vary greatly, while in the monsoon areas the reversal of the currents caused by the opposite winds exercise a great influence on the movements of the water far beyond their own limits, and anything like a prediction of the precise direction and rate of an oceanic stream can never be expected.

The main facts, however, of the great currents can be most certainly and simply explained in this manner.

The trade winds are the prime motors. They cause a surface drift of no great velocity over large areas in the same general direction as that in which they blow. These drifts after meeting and combining their forces eventually impinge on the land.

They are diverted and concentrated and increase in speed. They either pour through passages between islands, as into the Caribbean Sea, are pressed up by the land, and escape by the only outlets possible—as, for example, the Strait of Florida, and form a great ocean current like the Gulf Stream—or, as in the case of the Agulhas current and the powerful stream which runs north along the Zanzibar coast, they are simply pressed up against and diverted by the land, and run along it with increased rapidity.

These rapid currents are eventually apparently lost in the oceans, but they in their turn originate movements of a slower character, which on again passing over shallow water or on meeting land develop once more into well-defined currents.

We find an analogous state of things on the western side of the Pacific, where the Japan current is produced in a similar manner.

The fact that on all western shores of the great oceans towards which the trade winds blow we find the strongest currents running along the coast, is almost enough of itself to prove the connection between them.

The westerly winds that prevail in higher northern and southern latitudes are next in order in producing great currents. From the shape of the land they in some cases take up and continue the circulation commenced by the trade winds; in others they themselves originate great movements of the water.

Compared to the great circulation from this source the effect of differences of temperature or of specific gravity is insignificant, though no doubt they play their part, especially in causing slow under-circulation, and in a greater degree the vertical mixing of the lower waters.

No drop of the ocean, even at its greatest depth, is ever for one moment at rest.

Dealing with minor points, the American officers of the Coast and Geodetic Survey have found after long and patient investigation that the velocity of the Gulf Stream in its initial and most marked part, the Strait of Florida, is greatly affected by the tide, varying as much as one-half its maximum rate during the twenty-four hours.

These American investigations are of greatest interest. They have extended over the whole area of the Caribbean Sea and its approaches, the Gulf of Mexico, and the Gulf Stream proper and its vicinity. In no other part of the ocean has observation of this detailed character been carried out, and they throw a great light on oceanic circulation. The 'Blake,' the vessel specially fitted for the purpose, has during the several years in which she was employed on this work anchored in over 2,000 fathoms water, or a depth of considerably more than two miles; a feat which would a short time ago have been deemed impossible.

One great point that has come out very strongly is the continual variation in the strength and direction of the currents, and the varying depths to which the surface current extend.

Eastward of the chain of the Windward Islands the general depth of the surface movement may be said to be about 100 fathoms, below which tidal influence is very distinct.

There is also a very plain backward flow of water, at depths which vary, caused by the submarine ridge which connects the Windward Chain of the West Indian Islands. These observations also generally support what I have already mentioned: that the velocity of a current depends on the strength of winds, possibly thousands of miles distant, which have given the original impetus to the water, and this, combined with tidal action when the current approaches or runs along a coast, will always cause uncertainty on the resultant velocity.

Dealing for yet another moment with the Gulf Stream, there are two points which have not been much dwelt upon, but which have a great effect on its power of bringing the modifying influence of its warm water as far as our shores.

The first is the prevention of its spreading, as it leaves the Strait of Florida, by the pressure of the portion of the equatorial current which, unable to get through the passages between the Windward Islands, is diverted to the north of the Bahamas, and bears down on the eastward side of the Gulf Stream proper, compressing it between itself and the cold water flowing southward along the American coast, and at the same time adding to its forces and maintaining its high temperature.

The second is that by the time the Gulf Stream has lost its velocity as a current, in about the vicinity of the Banks of Newfoundland, it has arrived in the region of the westerly winds, that is of winds whose average direction is from west; whose influence, causing a surface drift somewhat comparable to that of the trade winds, bears the water onward to the British Islands and Norway. Without these prevailing westerly winds the warm water of the Gulf Stream would never reach these shores.

The depth to which the surface currents extend in other parts is little known. Direct observations on under-currents have been rare.

In the first place, it is not an easy observation to make. Apparatus has generally to be improvised. This has usually consisted of some form of flat surface lowered to the required depth, and suspended in the water by a buoy, which presents to the resistance of the upper stratum a very much smaller area than that of the surface below.

More perfect machines have been devised, notably, that used by the Americans in their West Indian experiments.

These, however, are delicate, and require so much care and experience in working, and so much time is wanted for such observations, that under the pressure of the more urgent requirements on surface movements in the interests of navigation very little has been done.

The 'Challenger' made some observations on the depth of the equatorial current in mid-Atlantic, but they were not very conclusive for lack of suitable appliances. They, however, tended to show that below 100 fathoms there was but little current.

It has been calculated theoretically that winds blowing steadily in one direction with the ordinary force of the trade winds would in 100,000 years by friction between the particles put the whole of a mass of water 2,000 fathoms deep, not otherwise influenced, into motion in that direction; but the direction and force of the trade winds are ever changing, and the actual strong currents of the ocean are not in the trade wind areas, but are the result of these drifts meeting one another and being compressed by the conformation of the land. We cannot, therefore, expect this theoretical effect to be realised.

One instance of the underrunning of one current by another is brought very plainly to our notice in the North Atlantic, to the east of the Great Bank of Newfoundland, where the icebergs borne by the arctic current from Baffin Bay pursue their course to the southward across the Gulf Stream running eastward.

These great masses of ice, floating with seven-eighths of their volume under the surface, draw so much water that they are all but wholly influenced by the under-current. A large berg will have its bottom as much as six or seven hundred feet below the surface. The only reason that these bergs continue their journey southward is the action of the cold under-current.

It was my good fortune to be ordered in 1872 to undertake a series of experiments of the currents and under-currents of the Dardanelles and Bosporus. They proved most interesting.

It was well known that a surface stream is almost continuously passing out of the Black Sea through the Bosporus into the Sea of Marmara, and again through the Dardanelles into the Mediterranean. Certain physicists, of whom Dr. W. Carpenter was one, were, however, of opinion that a return current would be found under the surface running in the opposite direction, and this I was enabled to demonstrate.

Though from the imperfection of our apparatus, which we had to devise on the spot, we were unable to exactly proportionate the quantities of water moving in the two directions, we found, whenever the surface current was rushing south-westward through these straits, that for a certain distance, from the bottom upwards, the water was in rapid motion in the opposite direction. It was an astonishing sight to behold the buoys which supported a wooden framework of 36 square feet area, lowered to depths from 100 to 240 feet, tearing up the straits against a strong surface current of as much as three and four miles an hour. It was as perfect an ocular demonstration of a counter under-current as could be wished, and the Turks, who watched our proceedings with much suspicion, were strongly of opinion that the Devil had a hand in it, and only the exhibition of the Sultan's firman saved us from interruption. In the investigation of these currents we found, as usual, that the wind was the most potent agent. Though the surface water from the Black Sea is almost fresh, and the bottom water of the heavy Mediterranean density of 1·027, it was found that when calm had prevailed the surface current slackened, and at times became nil, whilst the under-current responded by a similar slackening.

The ordinary condition of wind in the regions of the Black Sea and Sea of Marmara is that of a prevalent N.E. wind. This causes a heaping up of the water on the south-west shores of those seas, precisely where the straits open, and the surface water therefore rapidly escapes.

These straits no doubt present abnormal characters, but, so far as surface currents are concerned, the long series of observations then made convinced me of the inadequacy of differences of specific gravity, which were here at a maximum, to cause any perceptible horizontal flow of water.

I have said that we were unable to define by direct observation the exact position of the dividing line between the opposing currents, but the rapid change in the specific gravity at a certain depth, which varied on different days, gave a strong indication that the currents changed at this point.

A Russian officer, Captain Makaroff, afterwards made similar experiments in the Bosporus, but with more perfect appliances, and he found that at the point where the specific gravity changed the currents also changed.

I have been anxious to obtain similar observations at the Straits of Bab-el-Mandeb, the southern outlet of the Red Sea, where somewhat similar conditions prevail. Here the winds are governed by the monsoons. For half the year the wind blows from the north down the whole length of the sea, causing a surface flow outwards into the Gulf of Aden, and a general lowering of the whole level of the sea of about two feet. For the other half of the year the wind at the southern end of the sea is strong from the south-east, causing a surface set into the Red Sea, over which the general level of the water rises, while the northerly wind continues to blow throughout the northern half.

At either of these times I think it is highly probable that there is an undercurrent in the opposite direction to that at the surface, but unfortunately the sea disturbance is great and observations are very difficult.

Observations were, however, made by Captain W. U. Moore in H.M.S. 'Penguin' in 1890, but at a time when the change of monsoon was taking place.

The result was peculiar, for it appeared that at a depth of about 360 feet the movement of the water was tidal, while the surface water was moving slowly in one direction—a result generally similar to that obtained by the Americans in the West Indies—but the direction of the tidal flow was directly opposite to what might have been expected, viz., the water ran in while the tide fell, and *vice versâ*.

More observations are, however, needed here before any certain conclusions can be formed.

The depth of the ocean is the next great feature which demands attention.

On this our knowledge is steadily, though slowly, increasing.

The whole of it has been gained during the last fifty years.

Commenced by Sir James Ross, whose means were very small, but who nevertheless demonstrated that the so-called unfathomable ocean was certainly fathomable everywhere, the sounding of the ocean has continuously proceeded. The needs of submarine cables have constantly demanded knowledge in this particular, and the different cable companies have had a large share in ascertaining the facts.

Expeditions, whose main object has been to obtain soundings, have been sent out, Great Britain and the United States taking the first place; but most maritime nations have aided.

In the immediate past the additions have mainly been from the soundings which H.M. surveying ships continually take whenever on passage from one place to another, from the work of our cable companies, and from United States vessels.

We have, as a result, a very fair general knowledge of the prevailing depths in the Atlantic, but of the Indian and Pacific Oceans it is very fragmentary. We have enough to give us a general idea, but our requirements increase as years roll on. It is a vast task, and, it may be safely said, will never be completed; for we shall never be satisfied until we know the variations of level under the water as well as we know those on the dry land.

It is hopeless to do more than to briefly sketch the amount of our knowledge.

First, as to the greatest depths known. It is very remarkable, and from a geological point of view significant, that the very deepest parts of the ocean are not in or near their centres, but in all cases are very near land.

One hundred and ten miles outside the Kurile Islands, which stretch from the northern point of Japan to the north-east, the deepest sounding has been obtained of 4,655 fathoms, or 27,930 feet. This appears to be in a deep depression, which runs parallel to the Kurile Islands and Japan; but its extent is unknown, and may be very large.

Seventy miles north of Porto Rico, in the West Indies, is the next deepest cast known, viz., 4,561 fathoms, or 27,366 feet; not far inferior to the Pacific depth, but here the deep area must be comparatively small, as shallower soundings have been made at distances sixty miles north and east of it.

A similar depression has been sounded during the last few years west of the great range of the Andes, at a distance of fifty miles from the coast of Peru, where the greatest depth is 4,175 fathoms.

Other isolated depths of over 4,000 fathoms have been sounded in the Pacific: One between the Tonga or Friendly Islands of 4,500 fathoms, one of 4,478 fathoms near the Ladrones, and another of 4,428 fathoms near Pylstaart Island, all in the Western Pacific. They all require further investigation to determine their extent.

With these few exceptions, the depth of the oceans, so far as yet known, nowhere comes up to 4,000 fathoms, or four sea miles; but there can be little doubt that other similar hollows are yet to be found.

The sea with the greatest mean depth appears to be the vast Pacific, which covers 67 millions of the 188 millions of square miles composing the earth's surface.

Of these 188 millions, 137 millions are sea, so that the Pacific comprises just one-half of the water of the globe, and more than one-third of its whole area.

The Northern Pacific has been estimated by Mr. John Murray to have a mean depth of over 2,500 fathoms, while the Southern Pacific is credited with a little under 2,400 fathoms. These figures are based on a number of soundings which cannot be designated otherwise than very sparse.

To give an idea of what remains to be done, I will mention that in the eastern part of the Central Pacific there is an area of 10,500,000 square miles in which there are only seven soundings, whilst in a long strip crossing the whole North Pacific, which has an area of 2,800,000 square miles, there is no sounding at all. Nevertheless, while the approximate mean depth I am mentioning may be considerably altered as knowledge increases, we know enough to say that the Pacific is generally deeper than the other oceans. The immensity, both in bulk and area, of this great mass of water, is difficult to realise; but it may assist us when we realise that the whole of the land on the globe above water level, if shovelled into the Pacific, would only fill one-seventh of it.

The Indian Ocean, with an area of 25,000,000 square miles, has a mean depth, according to Mr. Murray, of a little over 2,000 fathoms. This also is estimated from a very insufficient number of soundings.

The Atlantic, by far the best sounded ocean, has an area of 31,000,000 square miles, with a mean depth of about 2,200 fathoms.

The temperature of this huge mass of water is an interesting point.

The temperature of the surface is most important to us, as it is largely on it that the climates of the different parts of the world depend. This is comparatively easy to ascertain. We know so much about it that we are not likely to improve on it for many years. We are quite able to understand why countries in the same latitude differ so widely in their respective mean temperatures; why fogs prevail in certain localities more than others; and how it comes about that others are subject to tempestuous storms.

On the latter point nothing has come out plainer from recent discussion than the fact that areas where great differences of surface temperature of the sea prevail are those in which storms are generated.

It is a matter of observation that in the region south of Nova Scotia and Newfoundland many of the storms which travel over the Atlantic to this country have their rise.

An examination of surface temperature shows that in this region the variations are excessive, not only from the juxtaposition of the warm water of the Gulf Stream and the cold water of the Arctic current flowing southward inside of it, but in the Gulf Stream itself, which is composed of streaks of warm and colder water, between which differences of as much as 20° Fahr. exist.

The same conditions exist south of the Cape of Good Hope, another well-known birthplace of storms. Here the Agulhas current of about 70° Fahr. diverted by the land pours into the mass of water to the southward, colder by some 25°, and the meeting-place is well known as most tempestuous.

South-east of the Rio de la Plata is another stormy area, and here we find the same abnormal variations in surface temperature.

Yet another is found off the north-east coast of Japan with the same conditions.

These differences are brought about by the mingling of water carried either by the flowing of a powerful current turned by the land into a mass of water of different temperature, as is the case off the Cape of Good Hope, or by the uprising of lower strata of cooler water through a shallow surface stream, as appears to be the case in the Gulf Stream.

A remarkable point recently brought to light by the researches of Mr. John Murray in Scotch lochs is the effect of wind on the surface temperature. It has been observed that wind driving off a shore drifts the surface water before it. This water is replaced by the readiest means, that is to say, by water from below the surface rising to take its place. As the lower strata are in all cases cooler than the surface, a lowering of the temperature results, and we find, in fact, that near all sea-shores off which a steady wind blows the water is cooler than further to seaward.

This has an important bearing on coral growth, and explains why on all western coasts of the great continents off which the trade winds blow we find an almost absolute dearth of coral, while on the eastern coasts, on which warm currents impinge, reefs abound, the coral animal flourishing only in water above a certain temperature.

Observations of the temperature of the strata of water between the surface and bottom have been of late years obtained in many parts. Compared with the area of the oceans they are but few, but our knowledge steadily increases every year.

The subject of the vertical distribution of temperature has not yet been thoroughly investigated in the light of the whole of the information which we now possess, but Dr. Alex. Buchan has been for some time devoting his spare time to the task, and it is a heavy labour, for the data obtained here and there over the world by different ships of all maritime nations are very difficult to collect and to appraise, but I understand that before long we shall have the result, which will prove very interesting, in the last volume of the 'Challenger' series.

It will readily be understood that observations on temperatures at great depths require great care. In the first place the thermometers must be most carefully manufactured. They must be subjected to rigorous tests, and they must be carefully handled during the operation. All observations are not of the same value, and the discussion, therefore, presents considerable difficulty and demands much discretion.

In the meantime we can state certain known facts.

We have learnt that the depth of the warm surface water is small.

In the equatorial current between Africa and South America, where the surface is of a temperature of 78°, at 100 fathoms it is only 55°, a difference of 23°, and a temperature of 40° is reached at 400 fathoms. In this region, so far as knowledge goes, the fall in temperature as we descend is most rapid, but generally speaking the same variations prevail everywhere.

In the tropical Pacific the temperature falls 32° from the surface, where it stands at 82°, to a depth of 200 fathoms, 40° being reached at from 500 to 600 fathoms below the surface.

Below the general depth of from 400 to 600 fathoms, the temperature decreases very slowly, but there is considerable variation in the absolute amount of it when we get to great depths in different parts of the ocean.

One of the most interesting facts that has been recognised is that in enclosed hollows of the ocean the bottom temperature is apparently much less than that of the stratum of water at a corresponding depth in the waters outside the submarine ridge that forms the enclosing walls, separating them from deeper areas beyond, and is, in all cases that have been observed, equal to that on the ridge. From this fact we are enabled to supplement our imperfect knowledge of depths, because if in a certain part of an ocean we find that the temperature at great depths is higher than we know exists at similar depths in waters apparently connected, we can feel certain that there is a submarine ridge which cuts off the bottom waters from moving along, and that the depth on this ridge is that at which is found the corresponding temperature in the outer waters. As a corollary we also assume that the movement of water at great depths is confined to an almost imperceptible movement, for if there was a motion that we could term, in the ordinary acceptation of the word, a current, it would infallibly surmount a ridge and pour over the other side, carrying its lower temperature with it.

A notable instance is the bottom temperature of the North Atlantic. This is nowhere below 35° F., although the depths are very great. But in the South Atlantic at a depth of only 2,800 fathoms the bottom temperature is but a little above 32° F., and we are therefore convinced that somewhere between Africa and South America, though soundings do not yet show it, there must be a ridge at a depth of about 2,000 fathoms.

We also come to the same conclusion with regard to the eastern and western portions of the South Atlantic, where similar differences prevail.

Again, the few temperatures that have been obtained in the eastern South Pacific show a considerable difference from those in the South Atlantic, and we are compelled to assume a ridge from the Falkland Islands to the Antarctic continent.

It is interesting that the investigation into the translation of the great seismic wave caused by the eruption of Krakatoa in 1883 led to a similar and entirely independent conclusion. The wave caused by the explosion in the Straits of Sunda reached Cape Horn, where by good chance a French meteorological expedition had erected an automatic tide gauge, but instead of one series of waves being marked on the paper there were two. A little consideration showed that the South Pole having directly interposed between Sunda Straits and Cape Horn, the waves diverted by the land about the pole would arrive from both sides.

One wave, however, made its appearance seven hours before the other.

Study showed that the earliest wave coincided in time with a wave travelling on the Pacific side of the pole, with a velocity due to the known depth, while the later wave must have been retarded in its journey *viâ* the South Atlantic. The only possible explanation is that the wave had been impeded by comparatively shallow water.

The evidence from bottom temperature was then unknown, and thus does one branch of investigation aid another.

In the Western Pacific the water is colder, a few bottom temperatures of a little over 33° F. having been found in the deep trough east of the Tonga Islands; but the North Pacific, though the deeper ocean—of enormous area and volume—is apparently again cut off by a submarine ridge. The north-western part of the Indian Ocean is for similar reasons assumed to be divided from the main body, the shallower water probably running from the Seychelles to the Maldive Islands.

Mr. Buchanan has pointed out why some parts of oceans, deep and vast though they be, are when cut off from communication with others warmer at the bottom.

Water can only sink through lower layers when it is the heavier, and though a warm surface current becomes from evaporation denser, its heat makes it specifically lighter than the strata below.

It is only when such a current parts gradually with its heat, as in travelling from tropical to temperate regions, that it sinks and slowly but surely carries its temperature with it, modifying the extreme natural cold of the bottom layers.

In the North Atlantic and Pacific we have such a condition. The great currents of the Gulf Stream and Japan current as they flow to the north sink, and in the course of ages have succeeded in raising the bottom temperature three or four degrees.

In the Southern Seas this influence is not at work, and, directly connected with the more open water round the South Pole, there is nothingto carry to the abysmal depths any heat to raise them from their normal low temperatures, due to the absence of any heating influence.

The ice masses round the South Pole have probably little or no effect on bottom temperature, as the fresher, though colder, water will not sink; and, as a matter of fact, warmer water is found at a few hundred fathoms than at the surface.

The lowest temperature ever obtained was by Sir John Ross in the Arctic Ocean in Davis Straits at a depth of 680 fathoms, when he recorded a reading of 25° F. This probably requires confirmation, as thermometers of those days were somewhat imperfect.

In the great oceans the greatest cold is found on the western side of the South Atlantic, where the thermometer stands at 32°·3 F., but temperatures of 29° F. have been obtained of recent years east of the Færoe Islands, north of the ridge which cuts off the deeper waters of the Arctic from the Atlantic.

Though scarcely within the limits of my subject, which is the sea itself, I must say a few words on the sea floor.

The researches carried on in the 'Challenger' revealed that while for a certain distance from the continents the bottom is composed of terrestrial detritus, everywhere in deep water it is mainly composed of the skeletons or remains of skeletons of the minute animals that have lived in the water.

In comparatively small depths we find remains of many shells. As the depth increases to 500 fathoms or so we get mainly the calcareous shells of the globigerinæ which may be said to form by far the greater part of the oceanic floor.

In deeper water still, where pressure, combined with the action of the carbonic acid, has dissolved all calcareous matter, we find an impalpable mud with skeletons of the silicious radiolaria of countless forms of the greatest beauty and complexity. Deeper still, *i.e.*, in water of—speaking generally—over 3,000 fathoms, we find a reddish-coloured clayey mud, in which the only traces of recognisable organic remains are teeth of sharks and cetacea, many belonging to extinct species.

What the depths of these deposits may be is a subject of speculation. It may be that some day, as mechanical appliances are improved, we shall find means of boring, but up to the present no such operation has been attempted.

On the specific gravity of the water of the sea I can say but little except that it varies considerably.

It is not yet known for certainty how far the specific gravities observed at various points and depths remain appreciably constant.

In localities where evaporation is great, and other influences do not interfere, it is evident that the specific gravity of the surface will be high—a consideration which observations confirm; but there are many complications which require more observation before they can be resolved.

In some few places repeated observations permit deductions, but taking the sea as a whole we are yet very ignorant of the facts bearing on this point.

The waves which for ever disturb the surface of the sea demand much study.

The greatest of these, and the most regular, is the tidal wave. On this many powerful intellects have been brought to bear, but it still presents many unsolved anomalies.

Lord Kelvin and Professor Darwin have demonstrated that the tidal movement is made up of many waves depending upon different functions of the moon and sun, some being semi-diurnal, some diurnal. The time of transit over the meridian, the declination of both bodies, create great variations; the changing distance and position of the moon and the position of her node, also have great effect, while the ever-varying direction and force of the winds, and the different pressure of the atmosphere play their part, and sometimes a very large part, on what is somewhat loosely known as the meteorological tide.

The amplitude of the oscillation of the water depending upon each of the astronomical functions varying for every point on the earth, the effect is that, each having a different period, the resulting mean movement of the water has most astonishing variations.

In some places there is but one apparent tide in the day; in others this phenomenon only occurs at particular periods of each lunation, while in the majority of cases it is the movements of each alternate tide only that appear to have much to do with one another.

Though after long observation made of the times and ranges of tides at any one spot they can now be predicted with great accuracy, for that particular place, by the method of harmonic analysis perfected by Professor G. Darwin, the meteorological tide excepted, no one can yet say what the tide will be at any spot where observations have not been made

Observations all over the world have now shown that there is no part where the tidal movement is so regular and simple as around the British Islands. This is more remarkable when it is found that the tides on the other side of the Atlantic —at Nova Scotia, for instance—are very complicated.

The minor tides, which in most parts of the world, when combined in one direction, amount to a very considerable fraction of the principal lunar and solar tides, and consequently greatly increase or diminish their effects, are in Great Britain so insignificant that their influence is trifling; but why this should be I have never yet found anyone to explain.

Nevertheless there are many very curious points about our tides which are plainly caused by interference, or, in other words, by the meeting of two tidal waves arriving from opposite directions, or from the rebound of the tidal waves from other coasts.

This effect, also, it has been so far found impossible to predict without observation. On our southern coasts, for instance; in the western part the tide rises about 15 feet, but as it travels eastward the range becomes less and less until, about Poole, it reaches a minimum of 6 feet. Farther east again it increases to Hastings, where the range is 24 feet. Yet farther east it again gradually diminishes. This is due to the reflection from the French coast, which brings another wave which either superposes itself upon, or reduces the effect of, the main tide advancing up the English Channel; but the details of such reflection are so complex that no one could forecast them without more knowledge than we possess.

There can be little doubt that to this cause, reflection, is mainly due the variations in the amount of mean range of tide which are found on many coasts at different parts; and as these reflected waves may arrive from great distances, and be many in number, we may cease to wonder at the extraordinary differences in range of tide which prevail, though it will be understood that this is wholly separate from the varying heights of each successive tide, or of the tide at different parts of each lunation, or at different times of the year, which depend upon the astronomical influences.

The actual height of the tide in deep water is small, but on passing into shallow water when approaching a shore, and especially when rolling up a gulf of more or less funnel shape, it becomes increased by the retardation caused by friction, and by compression laterally, and hence the height of the tide on a coast affected by other causes is greater than in the open sea.

The oceanic tide wave is supposed to be from 2 to 3 feet in height, but as this has been assumed from observations made at small oceanic islands where, although the magnifying influences mentioned are at a minimum, they still exist, we wait for precise information until some means of actually measuring the tide in deep water is devised.

The waves due to wind, though not so far-reaching in their effects as the majestic march of the tide wave, are phenomena which are more apparent to the traveller on the ocean.

The deep sea in a heavy gale presents, perhaps, the most impressive manifestation of the powers of Nature which man can behold, and doubtless many of us have experienced feelings that may vary from awe and wonder to sheer delight, according to the temperament of each individual, at for the first time finding himself face to face with this magnificent sight, though I rather fear that discomfort is the prevailing feeling that many carry away.

The height to which storm waves may rise has never been very satisfactorily determined. Apart from the difficulty of the task and the small number of people who will address themselves to it when they have the chance, it is but rarely that any individual sees really abnormal waves, even though he may be at sea all his life.

Different heights for what are called maximum waves have been recorded, and they vary from 40 to 90 feet from crest to hollow.

All we can say is that the most probable figure is about 50 or 60 feet.

These great storm waves travel very far. In some cases they convey a warning, as their velocity always far exceeds that at which the storm is travelling. In others they intimate that a gale of which no more is seen has occurred somewhere—it may be many miles distant.

When they have travelled beyond the limits of the wind which raised them, they lose the steepness of slope which characterises them when under its influence, and become an undulation which is scarcely noticed when in deep water.

On approaching shallow water, however, they are again apparent, and the 'rollers' that occur unperiodically at various places in latitudes where gales never occur would seem to be caused by such waves, originating in areas many thousands of miles distant. Such appears to be the origin of the well-known rollers at Ascension and St. Helena, where the rocky and exposed nature of the landing has caused this phenomenon to be especially noticed.

Other rollers are, however, undoubtedly due to earthquakes or volcanic eruptions occurring in the bed of the sea.

Many of the great and sudden waves which have caused devastation and great loss of life on the shores of western South America are referable to this cause.

Observations to enable the focus of such a disturbance to be traced have generally been lacking, but it is probable that where the wave has been large the point of origin has not been far distant.

In one notable instance the conditions were reversed. The point of origin was known, and the distance to which the resulting wave travelled could be fairly satisfactorily traced.

This was the great eruption in the Straits of Sunda, in August 1883, which locally resulted in the disappearance of the major part of the island of Krakatoa, and the loss of nearly 40,000 lives, on the neighbouring shores of Java and Sumatra, by the huge wave which devastated them.

The records of automatic tide gauges and the observations of individuals enabled the waves emanating from this disturbance to be followed to great distances. These waves were of great length, the crests arriving at intervals of about an hour, and moving with a velocity of about 350 miles an hour, were about that distance apart.

The waves recorded at Cape Horn were apparently undoubtedly due to the eruption, and travelled distances of 7,500 miles and 7,800 miles in their course on either side of the south polar land.

They were only 5 inches in height above mean level of the sea, while the waves recorded at places on the southern part of Africa, at a distance of about 5,000 miles from the scene of the eruption, were from 1 to 2 feet high, the original long waves being of an unknown height, but probably did not exceed 10 or 15 feet.

No other such opportunity of testing the distances to which great waves may travel has ever occurred, and as such a catastrophe as gave rise to them could scarcely be repeated without similar loss of life, it may be hoped we shall not live to see another, interesting though the discussion of the numerous phenomena were.

The movement of the particles of water due to the tide wave extends to the bottom of the deepest water, and doubtless plays an important part in keeping up a constant motion in the abysses, but the depth to which the action of the surface waves originating in wind reach is still but little known by observation.

If, however, we study the contour of the bottom off the shores of land exposed to the full influence of the great oceans, we are struck by the very general rapid increase of slope after a depth of about 80 to 100 fathoms (500 to 600 feet) has been reached.

It appears probable that this is connected with the depth to which wave action may extend, the fine particles brought down by rivers or washed from the land by the attrition of the breakers being distributed and gradually moved down the slope.

When we examine banks in the open sea we find, however, that there are a great many with a general depth of from 30 to 40 fathoms, and the question arises whether this may not be the general limit of the power of oceanic waves to cut down the mass acted upon when it is fairly friable.

The question has an interesting bearing on the subject of the ever-debated origin of coral atolls, for this is the general depth of many large lagoons; and granted that the sea can cut down land to this depth, we have at once an approach to the solution of the problem of the formation of bases of a suitable depth and material upon which the coral animal can commence operations.

This question also awaits more light, and I merely offer this remark as a suggestion.

It is, however, somewhat remarkable that in recent cases of volcanic islands piled up by submarine eruptions, they have all been more or less rapidly washed away, and are in process of further diminution under the surface.

Observations on the mean level of the sea show that it constantly varies, in some places more than others.

This subject has not yet been worked out.

In some localities it is plainly due to wind, as in the Red Sea, where the summer level is some two feet below that of winter, owing to the fact that in summer the wind blows down the whole length of the sea, and drives the water out.

In many places, as in the great estuary of the Rio de la Plata, the level is constantly varying with the direction of the winds, and the fluctuation due to this cause is greatly in excess of the tidal action.

In others the cause is not so clear.

At Sydney, New South Wales, Mr. Russell found that during eleven years the level was constantly falling at about an inch a year, but by the last accounts received it was again stationary.

The variations in the pressure of the atmosphere play an important part in changes of sea level.

A difference of one inch in the barometer has been shown to be followed by a difference of a foot in the mean level of the sea, and in parts of the world where the mean height of the barometer varies much with the seasons, and the tidal range is small, this effect is very marked.

Of any secular change in the level of the sea little is known. This can only be measured by comparison with the land, and it is a question which is the more unstable, the land or the water—probably the land, as it has been shown that the mass of the land is so trifling, compared with that of the ocean, that it would take a great deal to alter the general mean level of the latter.

All the points connected with the sea that I have had the honour of bringing before you form part of the daily observation of the marine surveyor when he has the chance; but I cannot refrain from also mentioning other duties, which are indeed in the present state of our knowledge and of the practical requirements of navigation the principal points to which he has to pay attention, as it may explain why our knowledge on so many interesting details still remains very imperfect.

Working as we do in the interests of the vast marine of Great Britain, the paramount necessity of good navigational charts requires that the production of such charts should be our principal aim.

It is difficult for a landsman and difficult even for a sailor who has never done such work to realise the time that is necessary to make a really complete marine survey. The most important part, the ascertainment of the depth, is done, so to speak, in the dark—that is to say, it is by touch and not by sight that we have to find the different elevations and depressions of the bottom of the sea.

In making a map of the land an isolated rock or hill stands up like a beacon above the surrounding land, and is at once localised and marked, but a similar object under the sea can only be found by patient and long-continued sounding, and may very easily be missed.

When it is considered that marine surveying has only been seriously undertaken for about 100 years, with a very limited number of vessels, we shall, I think, understand how in the vast area of the waters, taking only those bordering the shores, many unsuspected dangers are yearly discovered.

Very, very few coasts have been minutely surveyed, and, setting aside for a moment the great changes that take place off shores where sandbanks prevail, I should be sorry to say that even on our own coasts charts are perfect.

Yearly around Great Britain previously unknown rocks come to light, and if this is the case at home, what are we to think of the condition of charts of less known localities!

Our main efforts, therefore, are directed to the improvement of charts for safe navigation, and the time that can be spared to the elucidation of purely scientific problems is limited.

Nevertheless, the daily work of the surveyor is so intimately connected with these scientific problems that year by year, slowly but surely, we add to the accumulation of our knowledge of the sea.

The following Papers were read:—

1. *On Current Polar Exploration.* *By* Col. H. W. Feilden.[1]

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2. *On a Recent Journey in the Valley of the Euphrates.*

By D. G. Hogarth.

This journey was undertaken for archæological reasons in order to see whether remains of Roman frontier works exist on the right bank of the Euphrates in a state of preservation similar to that of Severus's road to Melitene, explored by Messrs. Hogarth and Munro in 1891. Mr. Hogarth's party consisted of Messrs. V. W. Yorke and F. W. Green and Lord Encombe.

'The great river Euphrates' was seen first at Khalfat. Here and for 300 miles up it can be crossed only by ferry boats of singularly rude construction; and the process of crossing with horses in such craft is exciting. The upper course of the river is rarely navigated and only by skin-rafts and swimmers on skins partly filled with grain. The depth and precipitousness of its gorge cause the Euphrates to be a serious barrier, and no road can long follow either bank. From Khalfat to Samsat the party had to cut off a bend, passing through villages of settled Kurds, tamed by the possession of agricultural wealth, and imbued through contact with Arabs and Syrians with orthodox Islam. Above Samsat the gorge soon becomes impassable, and dangerous rapids begin. The party made straight across Taurus, meeting great difficulties from narrow paths on precipices and soft snow. Descending near Malatia they made their way past the junction of the northern and eastern forks, about whose names and respective claim to be the main stream there seems much error in maps. The natives call the northern fork *Murad*, not *Kara Su*, and consider it the main river. The name *Frat* is known, but little used. North of the junction, where the Kurdish mountains hang over the left bank, the scenery is very grand indeed. The party continued to follow the river up to Erzingan.

The Kurds here are heretical and wilder than in the south. The Armenians are less servile than ordinary, but, being alive to the religious, social, and geographical difficulties in the way of independence, would gladly be left alone by agitators. There is little evidence of wanton oppression, least for religion's sake. Less is heard in the country than out of it of Kurdish tyranny. Armenians are well off in many respects, better in some than poor Moslems. Their condition is not improved, but the reverse, by irresponsible and otiose expressions of sympathy in Europe. Geographical considerations go far to preclude Armenia from becoming again a nation. Legionary camps were found at Samosata and Satala, but none at Melitene. A magnificent Roman bridge exists near Kiakhta and ruins of others, but no milestones or roadway connecting frontier forts, two of which were discovered. The reported walls along the bank south of Taurus were found to consist of ruins of an aqueduct. The river itself formed the most impassable of frontiers: it might well have seemed that the angel's vial must be poured out on the great river Euphrates, and the waters thereof dried up ere the way of the kings of the East could be prepared.

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3. *On Russian Armenia.* *By* Dr. A. Markoff.[2]

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4. *Montenegro.* *By* W. H. Cozens-Hardy.

Montenegro, since the Berlin treaty, has nearly doubled in area. The old Montenegro, which lies near the sea, is made up of bare limestone mountains enclosing fertile basins, the average height of the country above the sea being 2,000 to 3,000 feet. The Zeta, flowing into the Lake of Scutari, is the chief river, but this part of the country is almost destitute of water, and the inhabitants are compelled to store snow for drinking. The small village of Cetinje, which forms the capital, lies in one of the mountain basins. In July 1893 the Montenegrins celebrated there the 400th anniversary of the establishment of the earliest Slavonic printing press, set up not far from Cetinje in 1493.

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[1] *Scot. Geog. Mag.*, 1894, p. 465.

[2] *Ibid.* p. 469.

In the new Montenegro to the north and west the geographical characteristics are quite distinct. Grassy downs, dense forests, and innumerable mountain streams are found, and there is excellent pasture for sheep. The two highest mountains are Kom and Durmitor, which are slightly under 9,000 feet high.

The Montenegrins are divided into clans and communes, and possess an elaborate system of local government. At present Montenegro is emerging from an Homeric state of society, and its future depends on the ability of its people to adapt themselves to less warlike pursuits.

FRIDAY, AUGUST 10.

The following Papers were read:—

1. *On the Bathymetrical Survey of the French Lakes.* *By* E. DELEBECQUE.

As the result of the author's soundings in most of the French lakes, he has produced a series of sheets, published in 1892 and 1893 by the Ministère des Travaux Publics, under the title 'Atlas des Lacs Français.' The soundings were in every case made by means of a steel wire mounted on a graduated drum, the revolutions of which indicated the amount of wire payed out. The form of apparatus at first used was that of the Swiss Bureau Topographique, subsequently that of Belloc was employed, but finally one designed by the author and only weighing 4 kilogrammes was adopted. The position of each sounding was determined, either from angular measurements of the graduated mast of the boat taken from the shore, or by sextant bearings of objects on shore taken from the boat. A number of lakes have been sounded more roughly than those laid down in the atlas, and many observations of temperature and of the chemical composition of the water have been made.

The atlas, which will be completed by the addition of maps of several lakes in the Jura and the Pyrenees, is only a part of a comprehensive work about to be published by the author. The lakes already mapped in the atlas are arranged as follows:—

Pl. 1. Lake of Geneva (the Swiss part sounded by M. Hörnliman, of the Bureau Topographique Fédéral) on the scale $\frac{1}{50000}$.

Pl. 2. Lake of Bourget, scale $\frac{1}{20000}$.

Pl. 3. Lake of Annecy, scale $\frac{1}{20000}$.

Pl. 4. Lake of Aiguebelette (Savoy), scale $\frac{1}{10000}$.

Pl. 5. Lake of Paladru (Isère), scale $\frac{1}{10000}$.

Pl. 6. Lakes of Brenets, St. Point, Romoray, and Malpas (Doubs), scale $\frac{1}{10000}$.

Pl. 7. Lakes of Nantua, Sylans, and Genin (Ain), scale $\frac{1}{10000}$.

Pl. 8. Lakes of Chalain, Dessus, Dessous, Marlay, La Motte, Grand Maclu, and Petit Maclu (Jura), scale $\frac{1}{10000}$.

Pl. 9. Lakes of Saffrey and Petit Chat (Isère) and of La Girotte (Savoy), scale $\frac{1}{10000}$.

Pl. 10. Lakes of Issarlés (Ardèche), Bouchet (Haute-Loire), Pavin, Chauvet, Godivelle, and Tazanat (Puy-de-Dôme), scale $\frac{1}{10000}$.

In all cases the configuration of the lakes is expressed by contour lines at intervals of 5 or 10 metres, and the position of each sounding is shown by a dot. It was impossible to add the land contours on the same scale, as the French staff-maps do not show them with sufficient exactness.

2. *On a Bathymetrical Survey of the English Lakes.*
By HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

Ten of the largest English lakes were sounded by the author, assisted by Mr. E. Heawood, Mr. Shields, and others, and the final discussion of the work enables the following tabular statement to be drawn up :—

Name	Length, Miles	Breadth, Yards		Depth, Feet		Area, Square Miles	Volume, Million CubicFeet
		Max.	Average	Max.	Average		
Windermere .	10·50	1,610	950	219	78½	5·69	12,250
Ullswater . .	7·35	1,100	827	205	83	3·44	7,870
Wastwater .	3·00	880	650	258	134½	1·12	4,128
Coniston . .	5·41	870	600	184	79	1·89	4,000
Crummock .	2·50	1,000	700	144	87½	0·97	2,343
Ennerdale .	2·40	1,000	800	148	62	1·12	1,978
Bassenthwaite .	3·83	1,300	950	70	18	2·06	1,023
Derwentwater .	2·87	2,131	1,270	72	18	2·06	1,010
Haweswater .	2·33	600	405	103	39½	0·54	589
Buttermere .	1·26	670	620	94	54½	0·36	537

There are two main types amongst these lakes, the shallow and the deep. The former, including only Derwentwater and Bassenthwaite, are the broadest of all the lakes, and they only average 18 feet in depth. The bed of these lakes may be roughly described as an undulating plain, grooved and ridged into shallow hollows, and low shoals running parallel to the long axis of the lake.

The second, or deep type, the shallowest of which has an average depth of 40 feet, comprises all the other lakes. Ennerdale combines the characteristics of both types, conforming to the deep type in its upper, to the shallow in its lower reach. They are long, narrow, sometimes winding like Ullswater, or slightly curved in outline like Wastwater and Haweswater. The most characteristic lie in long narrow valleys with steeply sloping sides, and the slopes are continued under water with almost equal steepness, in some cases with greater steepness, and terminate in an almost flat floor. The typical form of this class of lake is thus a steep-sided flat-bottomed trough, diversified along the slopes by the still steeper conical mounds of *débris* thrown down at the mouths of streams.

3. *On the Currents of the Faeröe-Shetland Channel and the North Sea.*[1]
By H. N. DICKSON, *F.R.S.E.*

The physical observations made by the author on board H.M.S. 'Jackal,' on behalf of the Fishery Board for Scotland, during August 1893,[2] were continued in November 1893, and in February and May 1894. The unusual atmospheric conditions during the year 1893 probably made the differences of temperature observed greater than the normal, and those of salinity less, at least during the earlier part of the work. The discussion of the observations leads to the following provisional conclusions :—

1. While the Atlantic current flowing over the Wyville-Thomson ridge attains its maximum velocity in winter, its speed is maintained during summer by the greater warmth of the upper layers of water in the Atlantic, and consequent higher level of the surface of that ocean compared with the Norwegian Sea. Passing over the ridge, the Atlantic current is cooled by mixture with the cold water of

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[1] The paper is published in the *Report of the Fishery Board for Scotland*, 1894.

[2] *Brit. Assoc. Report*, 1893, p. 835.

the Norwegian Sea lying at the bottom of the Faeröe-Shetland Channel, and loses its horizontal motion. The warmer the Atlantic current, the more rapidly does this mixture take place. Hence in a hot, windless summer a mass of Atlantic water, extending to a great depth, tends to collect on the northern and north-western edge of the North Sea bank.

2. At all seasons Atlantic water is drawn from the Faeröe-Shetland Channel and forced into the North Sea by the tides between Orkney and Shetland. The tidal streams run N.W. and S.E., and an eddy is formed to the north-west of the Orkneys, into which North Sea water is drawn, and perhaps also water from below.

3. As the season advances the surface water of the North Sea becomes warmer, the upper layers probably receive smaller supplies of fresh water, but they become specifically lighter than the under layers, which they protect from the warming influences of the atmosphere. The upper layers becoming ultimately warmer than the Atlantic current, the surface of the North Sea becomes higher, and the surface water spreads outwards into the Faeröe-Shetland Channel, checking the surface supply of Atlantic water.

Meanwhile, the mass of Atlantic water, collecting at the edge of the North Sea Bank, seeks entrance into the North Sea. Mixing with the cold bottom water already there, it increases its salinity, but reduces its specific gravity by warming it, and, at a certain stage of mixture, the temperatures and salinities of the two waters combine to form a ridge or axis of maximum specific gravity. This axis, which probably runs N.E. from Shetland in the end of May or in June, turns slowly toward a N. to S. direction, and moves eastward. As it retreats, Atlantic water is gradually admitted round the north end of the Shetlands, passes down the east side of the groups, joins the tidal stream at the south end, and, guided by the axis of heavy water, is distributed along the east coast of Scotland, probably during July and August. Later in the summer, as the axis retreats still further, the Atlantic water is probably distributed more towards the eastward, perhaps until the latter part of September, when the diminishing supply from the Faeröe Channel, and the increasing outflow from the eastern side of the North Sea, bring about a gradual return to the conditions with which we started.

Obviously the controlling conditions are complex, but it appears that the greater the winter cold and the spring supply of ice-cold water from the continent, the more slowly will Atlantic water penetrate into the North Sea below the surface; and the warmer the summer, the more will the surface supply be checked. At the same time, the warmer the summer the larger the quantity of Atlantic water seeking admission, and the greater its thermal power to drive back the axis of maximum weight.

4. *On Geographical Photography.* *By* JOHN THOMSON.

The paper dealt with the difficulties experienced by travellers in the use of photography as an aid to exploration. The purposes of photography referred to did not include surveying, but merely the production of pictures showing ethnographic types, characteristic scenery from the geographical rather than the artistic point of view, and the details of artificial structures.

The necessity of proper training in the principles as well as the practical methods of photography was insisted on. Practical hints were given for the preservation and use of dry-plates, and for the successful development of negatives in tropical countries.

A series of travellers' photographs illustrating the excellences and the defects of such work was shown by the lantern.

5. *A New Light on the Discovery of America.*
By H. YULE OLDHAM, *M.A.*, *F.R.G.S.*

The development of America has had such a vital effect on the British Isles—removing them from an obscure situation on the outskirts of the known world to their true geographical position as the centre of the land masses of the globe—that everything relating to its discovery is of exceptional interest.

It is now well known that Columbus's famous voyage in A.D. 1492 opened the way to the settlement of the New World. It is not so well known that it had been visited before his time.

A glance at the map of the Atlantic Ocean will show the three easiest points of access.

(1) North America, by means of the convenient stepping-stones, Iceland and Greenland.

(2) Central America, with the help of the steady N.E. trade-winds.

(3) Brazil, in South America, which is not only the nearest point to the Old World, but has the additional advantage of winds and currents tending in its direction.

There can be little doubt that America was visited by Norsemen about A.D. 1000 by the first route. Tradition and the records of some early maps, which show large land masses as far west of the Azores as they are west of Europe, seem to indicate that the second route had been possibly utilised early in the fifteenth century, but the third and easiest was not available till the West African coast as far as Cape Verde had been discovered.

It was in A.D. 1445 that Cape Verde was for the first time rounded by one of the exploring expeditions despatched from Portugal by the indefatigable Prince Henry.

There is good reason to believe that only two years later Brazil was reached.

At that period great activity prevailed in Portugal; a large and increasing number of ships were yearly despatched along the West African coast. Nothing is less improbable than that one of these vessels should have been carried out to sea and driven to the coast of Brazil; and to show that this actually occurred we have documentary evidence.

There is at Milan a remarkable manuscript map, dated A.D. 1448, drawn by Andrea Bianco, of Venice, one of the best known of the map-makers, who worked in the first half of the fifteenth century. On this map are shown for the first time the results of the Portuguese discoveries as far as Cape Verde; but in addition there is drawn at the edge of the map, south-west from that cape, in the direction of Brazil, a long stretch of coast line labelled 'Authentic Island,' with a further inscription to the effect that it stretches '1,500 miles westwards.' Such a name and inscription are quite exceptional on maps of this kind, and must have been due to definite information.

Antonio Galvano in 'The Discoveries of the World,' published in the middle of the sixteenth century, says that in A.D. 1447 a Portuguese ship was carried by a great tempest far westwards until an island was discovered, from which gold was brought back to Portugal.

As Bianco's map of A.D. 1448 was made in London, it is likely that it represents information about this voyage derived in Portugal, where Bianco probably called on a voyage from Venice to England.

The conclusion to be drawn is that South America was first seen in the very year in which Columbus is believed to have been born by one of the Portuguese explorers despatched by Prince Henry the Navigator.

6. *Explorations in the Sierra Madre of Mexico. By* OSBERT H. HOWARTH.

A comparison is made of physical features common to the whole western range of North America from Oregon to Guatemala, illustrated by slides, and by notes from other ranges of great extent, *e.g.*, the Great Atlas and the Caucasus.

The means and incidents of travel in the Mexican ranges described and compared with those of the Rocky Mountains and Sierra Nevada.

The variations of climate in the Sierra Madre, and their effect upon mountain dwellers and their habits and industries, including certain of the isolated Indian tribes and the cave-dwellers of Sonora and Chihuahua, are illustrated by author's experiences in crossing the main range in Sonora, Sinaloa, and Michoacan, compared with similar experiences in Oregon, Colorado, New Mexico, and California.

The probable source of origin of Sierra Madre races, viz., North American, South American, and Asiatic, is discussed and illustrated by description of various antiquities, including villages, tombs, cave fortifications, and gardens, discovered or visited by author.

Incidents are given showing the gradual fusion of these races into the existing Mexican nation of to-day, and the extent to which a few families still remain unabsorbed; as in the case of the Apaches in Sonora, the Cota Indians in Durango, and the Zapotecas of the Tehuantepec Isthmus.

Certain peculiarities in the geological structure, vegetable productions, and fauna of the Sierra Madre are noted, together with legends and traditions amongst the primitive inhabitants arising out of known facts connected with them.

The extent of mountain country in Western Mexico still practically unexplored is shown by comparison with modern maps, which are entirely vague and imperfect in every instance, excepting where the State authorities have made some attempt at actual survey, owing to the necessity of defining mining claims.

The watersheds and their discharges are pointed out, with general description of the great lakes of Chapala, Patzcuaro, and Cuitzeo.

Also some description of the pine forests above the timber-line, the summits above snow-line (compared with those of North America), and the present seats of volcanic activity, and their relation to seismic disturbance along the Pacific coast.

The author's view is given as to the structural history of the western coast-line, and the very slight changes which have probably occurred in it since the Palæozoic period.

MONDAY, AUGUST 13.

The following Papers and Report were read:—

1. *On a Visit to British New Guinea.* *By* Miss FRANCES BAILDON.

The author and her brother visited British New Guinea in 1891 as guests of the Rev. J. Chalmers, the well-known missionary. They reached Port Moresby in a Queensland Government schooner of sixty-eight tons register on August 15, and after a short stay continued this journey westward for 150 miles to Motu-motu, where the native villages were visited. A canoe voyage was then undertaken to the inland village of Movi-avi, where the natives were suspicious and dangerous. After returning to Port Moresby by the same route a visit was paid to Kerepuna, and Hood Bay was left for Cooktown in Queensland on September 2.

2. *Report of the Committee on the Climatology of Africa.*
See Reports, p. 348.

3. *On a Journey in the Libyan Desert.* *By* H. WELD BLUNDELL.[1]

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[1] *Scottish Geographical Magazine*, 1894, p. 472.

4. *On Bhutan and the Himalayas east of Darjiling.*
By Col. H. Godwin-Austen, *F.R.S.*

5. *On the best Method of Aiming at Uniformity in the Spelling of Place-names.* *By* G. G. Chisholm, *M.A.*, *B.Sc.*

The purpose of this paper is to show in the first place that the indispensable preliminary requirement with a view to the end stated is to have an adequate scheme of orthography, not adequate in the sense of providing a separate sign for all articulate sounds, but through making up for the deficiency of such signs by clear rules to be followed with respect to the sounds for which signs are lacking. To leave it to the individual judgment to decide what is the nearest sound represented in the scheme to one for which no express provision is made is bound to lead to confusion. The inadequacy of the latest version of the Royal Geographical Society's scheme from this point of view is then pointed out, and suggestions of remedies are made. It is contended that the recognition of customary spellings under Rules 2 and 7 of that scheme, reasonable and indeed inevitable as such recognition is, imperatively demands the drawing up of schedules of such recognised spellings as supplements to the scheme. The addition of some subordinate rules likely to promote the efficiency with which the scheme is carried out is next recommended. Attention is drawn to special difficulties in connection with Russian and Greek names, and reasons are given for entertaining the hope that, with the aid of Oriental scholars, special rules might usefully be framed with regard to the spelling of Chinese and Indo-Chinese names. Finally, it is urged that, once an adequate scheme adequately expounded is adopted, it would be of great importance to make special arrangements to secure the co-operation of all contributors to the 'Geographical Journal' and other geographical periodicals, of publishers and authors, and, above all, of the newspaper Press, towards getting the scheme carried out.

TUESDAY, AUGUST 14.

The following Papers and Reports were read:—

1. *On Researches by the Prince of Monaco in the North Atlantic and Mediterranean during the Summer of* 1894. *By* J. Y. Buchanan, *F.R.S.*[1]

2. *Report of the Committee on Observations in South Georgia or other Antarctic Island.*—See Reports, p. 358.

3. *On the Jackson-Harmsworth Arctic Expedition.*
By A. Montefiore.

4. *On the Geographical and Bathymetrical Distribution of Marine Organisms.* *By* John Murray, *LL.D.*

5. *Report of the Committee on the Exploration of Hadramout.*
See Reports, p. 354.

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[1] *Geographical Journal*, 1894, p. 368.

[6. *On the Geography of Lower Nubia.* *By* SOMERS CLARKE, *F.S.A.*

The paper was chiefly confined to that part of Lower Nubia which will be flooded by the proposed Nile reservoir. The difference in size and colour-effect of the scenery in the valley of the Nile above and below Assuan were noticed. The Wadi Kenus, the abode of the Beni Kensi tribe, is nearly coincident with the projected Nile reservoir, and if the proposed scheme is carried out the population to be displaced numbers about 30,000, inhabiting a cultivated area of some 10,000 square acres (?). Population in the Ptolemaic times must have been greater, as there are tracts about Korti and Dakkeh, once under cultivation, now abandoned. In the Dodeka-Schoenus there are a number of temples and remains of antiquity within the district thus named, a further proof of considerable population; and the district is protected by a line of forts, some of very high antiquity, some of later date. The existence of Egyptian civilisation side by side with the ruder customs of the natives is especially to be observed in the method of burial. The present inhabitants on the course of the Nile valley from Assuan to Wadi Halfa exhibit very slight variations in modes of dress, particularly among the women. Men go to Cairo, women stop in the villages, so that the men adopt ordinary dress of fellaheen in Egypt.

The manner of building houses from lumps of earth, crude brick, with flat wooden or vaulted brick roofs constructed in the same way as those used by the ancient Egyptians was noticed. Reed shelters are also in use.

Not only the unique antiquities but the present people, with all life, animal and vegetable alike, are affected by the projected reservoir. In view of the contemplated destruction it is of the utmost importance to make an exhaustive scientific investigation of the valley before it is submerged.

7. *On a New Representation of the Vertical Relief of the British Isles.*
By B. V. DARBISHIRE.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

PRESIDENT OF THE SECTION—Professor C. F. BASTABLE, M.A., F.S.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

THE long period that has elapsed since the British Association last met in Oxford, covering as it does the life of an entire generation remarkable for activity in all departments of scientific work, would of itself suggest at least some passing notice of the changes that have taken place, and the progress realised in the subjects assigned to this section.

But some special reasons combine to give increased interest to a comparison between the position of economic science in 1860 and at the present day. What is usually known as orthodox political economy had taken its final shape and reached its highest point of practical influence just at the time when Nassau W. Senior, one of its most typical expositors, was chosen to preside over Section F. at its first meeting here. Far better even than J. S. Mill, Senior represented the strong and weak points of the English school. Clearness of thought, a firm grasp of elementary principles, and complete freedom from the disturbing influence of sentiment, are distinguishing marks of the compact treatise in which he set forth the chief doctrines of Economics, and they are equally shown in his presidential address. Political economy, he maintains, is a science and nothing else, limited in its scope to the subject of wealth, and concerned rather with mental than with physical phenomena. This very precision and rigid limitation naturally tended to produce some of the less admirable characteristics of the normal 'political economist.' Undue insistence on the omnipotence of purely material motives, a somewhat cynical disregard of the moral forces that influence human action in respect to wealth, and a certain love of paradox, especially in cases where popular prejudice was concerned, may be traced in Senior's writings as in those of most of his contemporaries, and go far to account for the intense repugnance felt by moralists and social reformers for a system which confined itself to one, and that which they deemed the lowest and coarsest side of human life.

Such as it was, however, with, and in part by reason of, its definiteness and its narrowness, political economy commanded the respect of a large section of the public and of its instructors and guides in the Press, who looked on it as supplying a rational code of industrial and commercial conduct. 'The recognised principles of political economy,' or 'the immutable laws of supply and demand,' were phrases that occurred as readily to a journalist in the sixties as 'the exploded doctrine of *laisser faire*' does to the leader-writer of to-day. The scientific doctrine of the economist applied to practice became the guiding rule of the practical man of business. Its influence on legislation is strikingly shown by two important triumphs gained in this very year (1860). The first and most enduring was the full and complete establishment of free trade as the basis of the fiscal policy of the United Kingdom by the budget measures of the year; the second, though transient, is even more instructive for our present purpose—viz., the declaration, in Cardwell's Irish Land Act, that for the future tenancies should rest 'on contract and not on tenure,' so that the relation between letters and hirers of land was reduced to a purely commercial one subject to the law of the market, and released, so far as legislation could secure that result, from all influence of sentiment or custom.

In such a condition of apparent prosperity, it was hardly likely that any apprehensions should be felt as to the future of economic study, and accordingly no signs of misgiving are to be found in Senior's brief but emphatic statements. His sole complaint is directed against the unfortunate tendency on the part of contributors of papers to wander from the region of science into that of art or practice, to the neglect of their proper subject, which afforded a sufficiently ample field for fruitful inquiries.

I need not say that this attitude of calm and assured confidence did not long continue, and it is equally unnecessary to attempt any description of the series of revolts against both the strict theoretical doctrines and some of the practical conclusions of the classical economy. Abundant information as to the leading phases of the movement and the chief actors therein is supplied in works so well known that any summary of their contents could be only the merest commonplace.[1] As affording a starting-point for further discussion I may, however, remark that three causes have most effectively operated in bringing about the changed position of our science—viz. (1) The influence of foreign, and chiefly German, workers in the same field; (2) the profound though peaceful political revolution by which power has been transferred to the working classes; and (3) the growth of the doctrine of evolution, which has been perhaps more potent in its effects on the social than even on the biological sciences.

As regards the first point, there is no room for doubt or question. With the exception of Say and Bastiat—who were chiefly valued as popularisers of English opinions—no foreign economist was at all known in England before the last thirty years. The mere suggestion that we had anything to learn from Germany, Holland, or Italy would have appeared ludicrous to Senior or McCulloch, or, indeed, to the educated public.[2] The true position of the foreigner was that of the humble disciple accepting gladly orthodox English teaching. This insularity of tone undoubtedly retarded progress in all departments of economics, but its evil effect was greatest in preventing any thorough consideration of the social and political groundwork on which all systems of economy rest, and to which all economic theories must, if they are to be enduring, pay adequate attention. The great and saving merit of German economic investigation lies in its unreserved acceptance of this fundamental fact, and it was in this very point that our English predecessors most signally failed. We should have escaped much narrowness and onesidedness of view if our writers had sought to understand and appreciate the Continental conception of the political sciences as an organised group of studies. Nor is it quite clear that this just ground of complaint has been altogether removed. Admirable efforts have been made by Leslie and others to diffuse a general knowledge of the labours of the historical school, and our principal text-books no longer pass over in silence the weighty contributions of foreign writers to special points of doctrine. Among professed students and teachers of economics there is a considerable and growing acquaintance with the products of foreign thought. Yet it seems as if the best lesson that they convey has not been thoroughly laid to heart, and that most of our attention has been directed to one particular school which makes the nearest approach to English methods, and is therefore least likely to help in correcting our peculiar failings. Is it not somewhat curious—might I not say discreditable—that the works of the eminent Roscher, whose loss every student of economic and political science must deplore, have found no English translator or even effective imitator?[1] Other instances nearly as glaring might be mentioned, leading to the general result that the distinctive differences of the English mode of treating economics are not sufficiently recognised, and further progress is for the time hindered.

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[1] Dr. Ingram's *History of Political Economy* (1888), pp. 221–235, and Professor Foxwell's letter on 'The Economic Movement in England,' *Quarterly Journal of Economics*, October 1887 (vol. ii. pp. 84–103), may be particularly referred to.

[2] 'Political economy,' said Professor Huxley in 1868, 'is an intensely Anglican science.'—*Lay Sermons*, p. 48.

Increased political power obtained by the class of manual workers has most markedly altered the prevalent tone of thought on industrial questions, and, if it has not caused, has at all events coincided with the adoption of more tolerant views respecting the effect of labour combinations. Fuller analysis has shown that the consequences of economic action are far more complex and more affected by surrounding conditions than upholders of the orthodox doctrines were willing to admit; but this modification in theory has been guided by the urgent pressure of non-expert opinion. It needed a very hard struggle to secure due recognition of the elements of truth in the trade-union position as to the determination of wages. But the mere substitution of 'working class' for 'middle class' dogma would not indicate any scientific advance. It is rather in the evidence of the close connection of economic facts with other forms of social activity that the true importance of the change consists. It is henceforth clear that no interpretation of industrial or other economic phenomena can claim to be adequate unless it takes into account the particular forms of social structure and the special political conditions which have helped to produce them.

More profound and far-reaching, both in its actual effects and in its still greater promise for the future, was the appearance of the principle of evolution, that became an active force from 1859. Its immediate influence in one branch of social study is well shown in the reception given to Maine's 'Ancient Law;' and though the economists did not at once recognise the full import of the method in respect to their own department of work, they saw its value in some special points, and thereby gave an opening for its further and more extensive employment.[2] The most obvious of the services that the new conception rendered was in bringing out the general similarity of the various sciences dealing with man, which again made examination of the bonds joining economics to the related subjects a more prominent object. Just as in biology the older inelastic views as to the nature of species and types gave way before the idea of innumerable gradations and transitional forms, so rigidity of definition and isolation of the study of wealth became no longer possible. Economic problems were found to be in contact at many points with social and political ones, and even within the artificially limited field of economics maintenance of the sharp lines between 'capital' and 'non-capital,' between 'rent' and 'interest,' between 'currency' and 'credit,' presented difficulties in face of the complexities of real life.[3]

Thus the disposition to take a broader view of the subject, and to widen the general conceptions and the 'setting' in which the received economic doctrines were presented, was encouraged by a series of influences operating in the same direction, and which, taken together, have left no inconsiderable mark on the actual condition of the science. The severest critic of the current political economy cannot, without unfairness, refuse to admit the improvement in tone, the greater thoroughness in the investigation of economic problems, and the wider range undertaken by the latest work of the English school. Much that was misleading or positively erroneous has been removed, and many valuable additions have been made to that part of the older system which has successfully stood the test of hostile examination. There is, besides, ample opportunity afforded for carrying on the work of reconstruction; indeed, it is chiefly because any suggestions, no matter how crude or imperfectly thought out, are likely to receive fair and candid consideration that I venture to notice some of the respects in which the revised and amended economic doctrine, as it appears to-day, seems to require further expansion and readjustment.

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[1] *The Grundlagen*, the least characteristic and original of Roscher's works, has been translated *in America*, but the other volumes of his '*System*' and his remaining writings are inaccessible to the English student.

[2] See J. S. Mill's *Principles*, Book II., chap. ii. § 3*n*, and Cairnes' *Political Essays*, p. 154, for recognition of Maine's services. But to the end neither seemed to understand the real bearing of the evolutionary mode of thought.

[3] See Marshall's *Principles*, Preface, pp. vi.–x., on this point.

In the first place I cannot feel that there is any adequate expression of the ultimate dependence of economics on that larger subject of study which treats of society as a whole. It is no doubt true that our leading economists state very distinctly the great importance of a science of society could it only be brought into a healthful existence; but such general confessions lose most of their value when accompanied by a very pronounced scepticism as to the establishment in the present or near future of any set of doctrines worthy of the name of sociology.[1] The very danger of this attitude lies in the fact that in one way it is so undeniably correct. When some of the more vehement assailants of the old political economy sought to contrast it to its disadvantage with a supposed social science into which it was to be absorbed, it was very natural to reply that political economy, however defective, was a fact, while sociology 'was best described as an aspiration.' There was no difficulty in showing that the so-called systems of sociology consisted of imperfectly collated facts and daring—often most unlucky—guesses as to the course of future events. The strict economist stood on very safe ground in contending against the dogmatism of the '*Positive Polity*.' But though the best attempts at a systematic treatment of social science have hitherto been grossly defective, this affords no excuse for neglecting a statement and analysis of the fundamental conceptions appropriate to social study and presupposed in all more special inquiries.

Political economy, like jurisprudence or political science proper, requires as its basis a fairly accurate comprehension of these preliminary parts of sociology. The questions—'What is a society?' 'What are the conditions necessary for its existence?' 'In what manner the chief social structures are produced?'—and many others of the same class should, I believe, be discussed as an introduction to the narrower economic problems. Moreover, some topics that seem purely economic have really a far wider significance. 'Division of labour,' 'Supply and demand,' and 'The population question,' must be regarded in a broader way than is possible within the limits that logical symmetry prescribes to the economist. In fact, the greater part of the matter to be found in the division of our text-books devoted to the subject of 'Production' is only introduced to supply the want of a due preparatory study of the leading features of what I may for the moment call the 'social organism.' That expression has unfortunately some unsatisfactory implications. It seems to give support to the idea that the social and political sciences may be regarded as mere appendices to biology, and that by a liberal adoption of the technical terms of that science we can turn out a complete and definite system without the trouble of continued effort applied directly to the study of social phenomena. This belief seems to me to be hopelessly mistaken, and I would protest as strongly as anyone against the 'manipulation of biological ideas and phrases'[2] as a mode of dealing with either economic or social questions. But the general conceptions which are needed to realise the broad features of social structure are not the peculiar property of any single science. Division of labour, *e.g.*, was recognised as a social truth long before its importance for the vital sciences was appreciated. It is therefore quite possible, without any illegitimate borrowing or routine imitation of inappropriate methods of exposition, to provide a satisfactory groundwork of social doctrine on which our economic theories can be securely based. Such a change in the usual method of treatment would be in harmony with the development of economics during the last twenty years, and could be attained without any sacrifice of the valuable material stored up in the standard treatises. Nor is it merely at the outset that systematic reference to social structures and conditions is required; all through the course of investigation that the economist has to pursue he will find that fresh light is thrown on even the minutest details by continually keeping in mind and striving as far as possible to realise the complete life of the society which exhibits them as one part of its varied activities.

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[1] See Sidgwick, 'Scope and Method of Political Economy,' in *Statistical Society's Journal*, vol. xlviii. p. 612; Marshall, *Principles*, Book I., chap. v. § 1; Nicholson, *Principles*, pp. 11–14.

[2] Nicholson, *Principles*, p. 12.

Great advances have already been made in this direction. No one can fail to perceive the contrast between the bareness of the manuals of Senior and Fawcett and—except in some particulars [1]—of J. S. Mill's 'Principles' as compared with the more elaborate presentation of our best modern text-books. Refined analysis of economic motives and critical discussion of abstract theoretical conceptions still hold a very large place; but the accurate exhibition of the growth of population and of the forms of industrial organisation, the tracing in their natural order of development of the 'village community,' the 'feudal system,' and of commercial land tenure,[2] do much more to promote the effective progress of scientific economics than the most brilliant efforts at deduction from unduly simplified premises. I would specially insist on the fact that it is the social basis rather than the slighter edifice of half-developed theory that gives life and power to our present work. We are thus led to the conclusion that one important step in the further progress of economics must be the fuller recognition of its dependence at the outset on, and its close relation all through its inquiries with, general social science, but that this reform does not need any extreme change in attitude—it rather involves the logical carrying out of an already pronounced tendency. No department or section of economics can escape this revision. Questions of value, money, credit, and foreign trade—to take topics that are supposed to be particularly amenable to abstract treatment—are more affected by social conditions than the theoretic economist will formally admit. Only through study of these influences can the materials needed for a correct theoretical solution be obtained, and due weight given to the several elements involved.

Another reform will be the natural, or rather necessary, consequence of that already urged. As soon as we get thoroughly accustomed to contemplating economic conditions in their actual forms as the special products of social life, it is but a matter of course to notice the remarkable differences and equally remarkable resemblances that different instances of the same economic institution or function will present. The banking system—to take a familiar example—is not the same in England as in France, while in the United States a third variety, or set of varieties, is to be found. Even within the same country there is no absolute uniformity. London banking differs from country banking, and Scotch banking, again, is distinct from either. Differences in environment will supply a partial explanation. A new country does not require and could not maintain the more complex arrangements suited to an old centre of industry and commerce. But peculiarities of social structure and even historical accidents count for much. We must go to history to find the origin of the Bank of England and the system of which it is the foundation, and to some peculiarities of the American Constitution for an explanation of the failure of the two attempts to permanently establish a similar institution in that country.[3] Now, what is true of banking is equally true of the monetary organisation, the economic features of the transport system—in a word, of every part of the economy of a nation or people. The attempts of different schools of economists to deal with this problem of variations must, I think, strike the unprejudiced observer as at best inadequate. Senior and McCulloch, representing very fairly the average economic opinion of their day, admitted the existence of diversities, but escaped their consideration by placing them outside the ring fence that bounded pure economics, or by regarding them as certain to disappear with the diffusion of sound views on the subject.[1] They in this way strove to keep up their favourite science as a real and positive one, while they shut out a number of troublesome questions. Mill and Cairnes boldly maintained that political economy merely dealt with tendencies, and was a hypothetical rather than a positive science; by throwing aside all the peculiarities and confining attention to the points of agreement certain formally valid results could be reached. To directly apply them to practice or regard them as a complete interpretation of concrete phenomena was simply an error in logic for which, when committed by others, the economist could not be held accountable.[2]

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[1] Mill's treatment of the earlier and ruder forms of land tenure is much more realistic and better 'nourished with specific facts;' but this departure, as he deemed it, from scientific precision was partly due to his strong interest in the Irish land question, and, as Whewell pointed out, is really an imitation of the method pursued by R. Jones in his admirable but premature book on *Rent* (1832).

[2] For population see the treatment by Marshall, *Principles*, Book IV., chaps. iv. and v.; for industrial organisation, *ib.* chaps. viii.–xii.; for the village community and feudalism, Nicholson, *Principles*, Book II., chaps. vi. and vii.; and compare with both the fuller treatment in the new edition of A. Wagner's *Grundlagen der Volkswirthschaft* (1892–3).

[3] See the several articles on 'Banking' in the new *Dictionary of Political Economy*; also C. F. Ferraris, *Scienza Bancaria*.

The English members of the historical school either neglect all but the crudest empirical classification, or suggest that each historical period must be treated by the use of special hypotheses suited to its particular condition, and thus succeed in combining their acceptance of a great deal of the traditional economic doctrine with a much more realistic treatment in respect to earlier times. All these methods seem defective, though in very different degrees. If the political economy of the middle of this century is to be regarded as a positive science, applicable without restriction of time or place, we get a ready explanation of the charge of 'undue absoluteness' so strongly urged by Knies,[3] and, it must be allowed, with considerable justice. There was from this point of view but one correct system in respect to each economic element. Large farms, free bargaining between independent labourers and employers, the single standard, and a banking system rigidly conforming to that prescribed by the Act of 1844, were some of the features of a well-organised economic society, any aberrations from which should be rectified at the first convenient opportunity. So narrow a conception could not long stand the test of wider experience, and accordingly it made way for the treatment of the subject as based on a series of hypotheses. By skilfully limiting and qualifying the leading doctrines it was not difficult to avoid the more obvious contradictions, and explain away persistently obstinate facts by regarding them as 'friction,' or as 'minor disturbing causes' which might be neglected without disadvantage. Used with reference to a given time and place, and with a wise selection of premises, the hypothetical deductive method yielded fruit of considerable value, but it utterly broke down in the attempt to deal with cases outside those included in the selected type, and even in dealing with them needed constant supplement and correction. Though the procedure of the economic historian appears specially devised to meet this defect, as it dwells on the differences found in the economic factors at different periods of a nation's history, it is far too narrow and too much complicated by the mass of details to render the service which is required. Economic history will, in conjunction with observation of existing conditions, ultimately furnish a rich store of materials out of which scientific results may be extracted, and this latter and most important part of the work will need systematic classification of the several types of institutions and conditions. To return to the example already given, it is necessary not merely to consider the abstract theory of banking under certain supposed conditions and its history in all countries so far as attainable. The principal object should be to ascertain the different groups into which banking systems can be scientifically arranged, and the ways in which each is produced by, and in turn reacts on the other parts of, the social system. Writers on sociology speak somewhat pretentiously of the '*consensus* of the social organism,' but they are expressing a real and important truth; for we cannot doubt that there are necessary relations, modifiable, indeed, within limits hard to define, but still present and not to be ignored by those who seek to interpret the movements of society. There is here an immense field as yet almost entirely overlooked. One minor instance may be noticed. We are all familiar with our own Treasury system, working smoothly and effectively through the agency of the Bank of England. We hardly realise that quite different arrangements are employed by the United States, and that France and Italy have a third system in force.[1] The origin and actual working of these types of financial administration and their relation to the economic and commercial institutions of the several countries in which they exist present an interesting subject of inquiry, and this is but one trifling instance of what is to be abundantly found in nearly every part of the field of economics. Until such points are studied in detail and by the comparative method, we cannot expect to obtain a completed body of economic doctrine resting on careful generalisations gathered from a sufficiently extensive experience.

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[1] Senior, *Introductory Lectures in the University of Oxford*, 1852, Lecture IV.

[2] J. S. Mill, *Essays on some Unsettled Questions*, Essay V.; J. E. Cairnes, *Logical Method*, Lecture II., § 3.

[3] *Politische Oekonomie*, 2nd. ed. 1883, III., viii., pp. 401 *seq.*

To the same defect is due the weakness in certain respects of our economic literature so far as monographs are concerned. Attention has often been called to the neglect of the problems connected with transport by English writers. We possess no recent works on the great subjects of (1) colonisation and (2) commercial crises that can bear comparison with the French and German studies.[2] It would almost seem that the attention of the younger economists is too much fastened on the passing aspects of the labour and currency questions to allow time to be devoted to calmer theoretic investigation. Even from the point of view of immediate personal advantage this is decidedly a mistake. No better advice could perhaps be given to the serious economic student at the opening of his work than to steadily avoid 'burning questions.' They are sure to be eagerly taken up by popular and untrained writers. Their scientific features are buried beneath a weight of prejudice and partisan feeling, and, last but not least, they so quickly become 'burnt out,' and public attention turns away to some other and equally temporary subject of debate. Careful examination of a really important question for the moment a little in the background must in the end prove more serviceable when the force of events compels practical men to direct their attention to it, and to consult those who have given time and trouble to its elucidation.

A third point on which some reform is needed concerns the organisation and teaching of the subject more than the advancement of scientific research, though it would not be without good results for the latter. It is the relation of economics, not to the outlines of social science that are its necessary basis, but to the other divisions dealing with cognate and similarly special branches of social life. There has hitherto been an unfortunate disposition to separate economics too sharply from these kindred studies. When the reformer argues that political science, jurisprudence, and the scientific principles of administration should be grouped along with economics he is met by the rejoinder that 'we should do one thing at a time,' that 'division of labour' is imperatively needed in so extensive a field of work. To so contend is to quite forget that 'division' implies 'combination' of labour, and that mere subdivision of tasks is not of itself advantageous. The contention, besides, goes too far for its purpose. Within the special district assigned to economics there are very different subjects which have to be temporarily kept apart. Nothing would be gained by interpolating a discussion of the 'wages question' into a treatise on 'money,' though no one would deny the connexion that exists between these two parts of economics. In the same way politics—in the scientific sense—and jurisprudence gain when taken together with economics, and repay that advantage by the additional light which they afford. One of the errors fostered by the stricter economists in this country was the belief that in political economy there was a peculiar department differing totally from other social and political sciences both in the rigour of its logic and the certainty of its conclusions. Such types of precision as geometry and logic were regarded as the proper models in the pursuit of this 'exact' science, whose cultivators were justly entitled to regard with condescension those engaged in seemingly less precise inquiries. The mistake committed was twofold. There was at once an over-estimation of the solidity of economic doctrines and an undue depreciation of the results obtained in politics, jurisprudence, and social ethics, with, as a natural consequence, the severing of subjects that should have been combined to form joint parts of a comprehensive whole. Some excuse may of course be made. Political economy had really some advantages which enabled it to develop more rapidly; it dealt with material interest when measurement was often possible, and its conclusions allowed of readier verification. It was, in fact, the first branch of social science that came under scientific treatment, and its earlier fruits were important enough to justify some pride on the part of those responsible for them. But this relative superiority seems to be steadily diminishing. Other, and for a time neglected, departments are freeing themselves from the confusion that surrounded their infancy, while the latest developments of economics tend to reduce the claim to peculiar rigour made in its behalf. But at any time the distinction was injurious. By presenting to the public a small and strictly enclosed section of social life as the sole part that admitted of scientific treatment it weakened both what it exalted and what it debased. Economics became henceforth something that had to be tacked on to any other subject or subjects as present convenience happened to dictate. Its true place and the various additions needed to give it consistency were altogether forgotten or ignored, until the study fell into serious discredit, from which it has only partially recovered. The true remedy is to be found in the combination of the several social sciences, together with the exclusion of everything that is extraneous. The extent to which this course will facilitate the progress of social studies may be in some degree conceived by considering the real unity of the field in which they work, and also the tastes and dispositions of those who make them a leading pursuit.

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[1] Kinley, *The Independent Treasury*, deals with the United States system; and Alessio, *La Funzione del Tesoro*, attempts a comparison of the several methods.

[2] Since Merivale's *Colonisation* (1842, 2nd edit. 1861) no English economist has made any contribution like those of Roscher and Leroy-Beaulieu to that subject.

The economist, the jurist, and the political philosopher are in the main engaged in examining the same phenomena, but from different points of view. A particular system of land tenure, a peculiar organisation of classes, even currency or banking regulations, have to be studied on their juristic and political as well as their economic side. In each case there are special features which demand most attention, but it is well to be able to appreciate the other and, for the purpose, less important aspects. Nothing will bring this truth more forcibly home to us than the ease with which the limits can be passed. When we see that much of Sir H. Maine's writing is really economic, that J. S. Mill in parts of his 'Principles' is dealing with juridical questions, we feel the closeness of the connexion and the evil of separation.[1]

From this necessity of dealing with a common material arises the disposition on the part of economists to pass on to politics and jurisprudence. From the time of Adam Smith to the present day there has been no lack of distinguished examples. The two Mills, Cairnes, Bagehot, Leslie, Hearn—to give but a few names—have made contributions to political and jural science little inferior to their services to economics. In our day have we not Professor Sidgwick's 'Elements of Politics' as the natural and appropriate sequel to his 'Principles of Political Economy?' So in Germany Roscher closed his academic career with a treatise on 'Politics,' which forms a worthy companion to his great economic *System*.

In the face of such impressive facts it is idle to maintain that economic science should be kept in isolation or joined at haphazard with other studies. The educational treatment of the matter is primarily one for the universities, but this Association can at least set a good example, and it is the better able to do this because it has always recognised statistics as an equal subject with 'economic science,' which in fact came in at a later time (1856). Now, as Senior allows, 'the science of statistics is far wider as to its subject-matter. It applies to all phenomena which can be counted and recorded.'[2] There is, he thinks, no limit to the objects to be included, provided that neither approval nor censure was expressed. Thus regarded, statistics is the handmaid of all the social sciences, and by releasing its votaries from this perpetual drudgery and allowing them to 'thresh out' a little of what they have gathered we may at once obtain a right constitution for this section as engaged in 'statistical and social inquiry.'

The reasons in favour of adopting an organisation of wider scope are strengthened by a reference to the actual position of economic science. After all the sustained attacks on it from different quarters it seems to have regained some of its lost ground, both as regards theory and practical influence. This partial recovery can be sustained and completed only by adjustment to suit the external conditions, and must be of the nature I have sought to indicate, otherwise the revival will be but temporary, and followed by more complete collapse.

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[1] See Maine, *Village Communities*, Lecture VI., and *Early Institutions*, Lectures V. and VI.; Mill, *Principles*, Book II., chap. ii.; Book V., chaps. viii. and ix.

[2] *Brit. Assoc. Report*, 1860, *Trans.*, p. 183.

Other countries are showing significant indications as to the true course of development. In the United States, where economics has taken so prominent a position, courses in social science are being established, and one university[1] has gone so far as to create a chair of general sociology, in addition to the special ones assigned to different branches of economics and politics. Another instance is much more instructive. France has long been known as the home of economic 'orthodoxy,' which has the 'Journal des Économistes' as its organ, and yet the last number of that eminently respectable and conservative journal opens with an excellent article on 'The State and Society' belonging altogether to the domain of political science.[2] Further on in the same number there is a report of an interesting discussion at the Political Economy Society of Paris on 'The Relation between Political Economy and Sociology,' where, though there were differences as to the exact nature of the relation, there were none as to its existence.[3] Similar indications are to be found in the movement of thought amongst economists in other European nations.

Practical considerations may also be put forward. It is highly desirable that certain professions—law, journalism, and public administration may be mentioned—should have economics as part of the training necessary for their exercise. To accomplish this object its combination with jurisprudence and political and administrative science in a common group seems by far the best way.[4] The strictly professional students would obtain a better and more suitable training, and it might be reasonably expected that some with genuinely scientific tastes would be led to take up social science as a regular pursuit, and contribute to its progress.

But it is in dealing with the practical problems that present themselves in ever-increasing number that this wider mode of treatment is most essential. To take first cases that are regarded as peculiarly within the domain of the economist—is it not true that commercial policy must largely depend on political and legal conditions? Even in carrying out the thoroughly wise and sound principle of free trade the British Government finds itself involved in many curious complications. Treaties and administrative regulations have to be taken into account. The political forces that guide the tariff policy of nations have their decided effects, and whether we desire merely to estimate the actual character of any particular policy, to form a rational forecast of the course that nations will take in the future, or to give judicious advice as to what should be done, we cannot limit ourselves to abstract economic theory or even to economic considerations. And this is equally true of the currency question. The weightiest arguments for and against bimetallism are, I believe, political rather than economic, while such social influences as habit and custom powerfully affect the possibilities of action that purely deductive reasoning from economic premises might appear to suggest.

The case becomes stronger when we turn to more fundamental and far-reaching problems. The essential character of the socialistic movement that is passing over Western civilisation cannot be properly judged if we look on it as merely economic. The ordinary antithesis between socialism and individualism, or, as it is often conceived, between self-sacrifice and selfishness, seems to me altogether misleading. The struggle is rather one between two distinct types of social organisation, one resting on the exaltation of the relatively modern institution of the State, the other deriving its principal force from the oldest and most enduring element of human society—the family. This aspect of the question will more and more come into prominence as the conflict proceeds. It is not the 'man of Nature,' the individual released from all restraints, who forms the unit in our modern 'individualistic' societies, but the individual with family ties and sentiments, and profoundly influenced by other than purely self-regarding motives. Collectivist socialism seeks to substitute for these natural agencies the comparatively artificial authority of the sovereign State. It aims at transforming private into public law, and it would make the life-work of the citizen one round of public administrative duties. The origin of this special system is obviously due to a particular social condition; it is the natural product of the factory and the workmen's club—*i.e.*, of a mode of living in which the family has unhappily sunk to a minor position, and in which the main uniting bond is that of 'comradeship.' How impossible it would be to bring all human societies under a form of regulation that presupposes the close contact of large masses of men, and how hopeless it is to expect its effective working while the domestic organisation and family affections retain their power, is a lesson that the study of social science in all its branches will most effectually teach.

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[1] Columbia.

[2] 'L'Etat et la Société,' by Maurice Block, *Journal des Économistes*, June 15, 1894, pp. 321–343.

[3] *Ib.* pp. 420–431. The remarks of MM. Worms, Leroy-Beaulieu, and Levasseur are instructive as to the opinions current among French economists.

[4] The rudiments of such a training existed in the case of the selected candidates for the Indian Civil Service, but the recent changes have practically removed this valuable part of the system previously in force.

That the time is ripe for this fuller development is, I think, clear from the interest with which the most speculative works on social development are received. A daring and suggestive discussion of the problem of social evolution, even if its basis is highly questionable, is sure of applause and a wide circle of readers. The most pressing duty on the part of those who desire to promote true knowledge is to secure that there shall be the proper preliminary training on the part of the writers and competent criticism of their productions.

Though I have dwelt mainly on the necessity for rearrangement and further progress, I should be sorry to leave the impression that I undervalue the great services of the English economists from Adam Smith to Senior and J. S. Mill. In its later developments that school was open to criticism. Some of its members committed serious faults, but they also possessed very redeeming merits. They may, perhaps—let us concede it—have been narrow-minded; they may have been hard-hearted, but in studying their chosen subject they were eminently 'level-headed.' They saw the working of material forces in their true balance, and were not unduly influenced by passing events. This intellectual sanity and just appreciation of the comparative weight to be assigned to the different elements operating on national life is well exemplified in an anecdote respecting Adam Smith himself, which we have on unexceptionable authority.

'Towards the close of the American War, when general despondency seemed to paralyse the nation, Dr. Smith, confident in the resources of the country, would not allow himself to despair of the commonwealth. On the news of Burgoyne's surrender at Saratoga Mr. Sinclair hurried to his friend with intelligence of the disaster, insisting that if affairs went on no better the nation must be ruined. "Be assured, my young friend," replied the imperturbable philosopher, "there is a great deal of ruin in a nation."'[1]

This attitude of calm, based on wide historical study and accurate estimate of the realities of things, is a valuable example which the older economists have left to their successors. At the present day, when we are always hearing of 'submerged tenths,' of depression in every branch of industry, of destructive monetary revolutions, and of land abandoned by its cultivators, while we seek to trace the reality and extent of these evils and to discover their causes, can we give a better reply to the eager enthusiast or the hasty innovator who insists that, unless his favourite nostrum is adopted, 'the nation must be ruined,' than to answer, with the calmness that knowledge of the forces that are working for social welfare produces, 'Be assured there is a great deal of ruin in a nation?'

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[1] Sinclair's *Memoirs*, vol. i. p. 37.

The following Papers were read:—

1. *On the Mathematical Theory of International Trade.* *By* Professor F. Y. Edgeworth, *M.A.*

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2. *Mechanics of Bimetallism.* *By* Professor Irving Fisher.

The bimetallic *régime* is figured as a system of hydrostatics by substituting for Jevons' curves reservoirs of water. Water represents commodity, and the water level, marginal utility. The system embraces three reservoirs, one for money and two for gold and silver in the arts respectively. The three being connected, the water seeks a common level. The method affords a theoretical criterion for distinguishing when bimetallism is and is not possible. The restoration of the old French ratio, even if possible, would cause depreciation, though not to the whole extent of the present difference. As compared with monometallism, bimetallism reduces fluctuations of value in the ratio of the combined breadths of two reservoirs to three.

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3. *On Factors of Production.* *By* H. Higgs, *LL.B.*

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4. *On Stock Exchange Taxation.* *By* J. Mandello, *Ph.D.*

Theory of taxes in the circulation of wealth. Taxes on capital as contrasted with taxes on land, &c. The French, Italian, German, and Austrian taxes on Stock Exchange transactions. What constitutes a good system of Stock Exchange taxation.

FRIDAY, AUGUST 10.

The following Papers were read:—

1. *The Church Army and the Unemployed.* *By the* Rev. W. H. Hunt.

The problem of the 'Unemployed' will always be a social as well as an industrial one, and the difficulties of it are probably greater because of unwise legislation and promiscuous relief. The complexity of it necessitates our rule for individual treatment and selection. In this country many methods have already been tried, and we recognise that no ultimate good can result to the nation from any work based upon a false economic principle. After working upon this rule for five years we are now able to say the social side of the problem, at least, is assuredly nearer solution than before. We aim at giving men the chance to earn and eat their own bread under healthy conditions with Christian environment. 'A Church, Army, Labour, Home: to these four things we owe everything we possess.' The manager and his wife act as 'father' and 'mother,' and the workers are called 'brothers.' We make every man feel his responsibility to earn his own living, and conform his habits to his economic surroundings. Idlers and drunkards are dismissed. We avoid pauperisation. Our small provincial Labour Homes being increased in number deter men from coming up to London. Sufficient trade can easily be secured, and the home is not calculated to disturb existing trade as a larger establishment might do. In them local influence is combined with a strong central government. The rules are cast into a simple form of agreement, and, being signed by each person, become a moral stimulus. Trade and fair rates are always charged, and paid. Every person is expected to earn six shillings per week for board and lodging, one shilling being then allowed for pocket money. Thrift is much encouraged. Full pay is allowed for two months, a trifle less the third month, and less again the fourth. The effect of this rule disposes of 'shiftless loafers,' and has been truly helpful to others. Help is allowed, if needed, sixteen weeks, after which twelve months must elapse before fresh application can be made. Each man is urged to do his best to obtain permanent work. We aim at decentralisation in finding places for men either at home or abroad. We believe in co-operation which economises labour and intensifies results, and the sound, unique, and valuable co-operation between the Poor Law and the Church Army has abundantly justified the Local Government Board in endorsing many annual subscriptions of ratepayers' money to our funds. The Church Army has tried, proved, and is still demonstrating an experiment with more than 2,000 people per annum, which, whilst it ensures a genuinely helpful chance to make a good start in life for at least 50 per cent. of that number, is at the same time a powerful object-lesson to the Church and the nation.

2. *On the Unemployed. By* Bolton Smart.

3. *On Prices, Wages, and the Standard of Value.*
By Edward Atkinson.

4. *On the Report of the Labour Commission. By* L. L. Price, *M.A.*

The Labour Commission has been engaged during the last three years in an inquiry of a very elaborate nature, and the question may naturally be asked, What has been the outcome of so large an expenditure of time and money? The answer depends on the expectations that have been formed. It is difficult to define the proper functions of a commission. Its temporary effect is undoubtedly the postponement of legislation, but this result is probably fraught more often with benefit than injury. A popular cry is frequently caught up and passed on with undiscriminating enthusiasm, and a commission brings to light the dangers and difficulties of the schemes which are thus propagated. A small commission of experts is the ideal form; but a large commission, representative of various interests, though it may lead to an inconclusive report, does secure a searching scrutiny of plausible proposals by hostile critics. The agitation for an eight hours' day has been thus treated by the Labour Commission, with the result of bringing into prominence the doubt attaching to the real meaning of the proposal and the difficulties attending its application to practice; and, in view of this uncertainty and difficulty, the Commission could hardly arrive at any other conclusion than that actually declared by the majority. They are content to present a summary of opposing views, and to recommend minor reforms. The minority, looking forward to the collectivist organisation of society, regard the legislative introduction of an eight hours' day with approval as a step towards that organisation, and treat from a similar standpoint the extension of the sphere of public employment. On various minor reforms majority and minority are substantially agreed. The main subject, however, of inquiry was the prevention of industrial disputes, and here the Commission found that so much had been already accomplished by voluntary experimental effort that little, if any, room was left for new suggestion. A mass of valuable material has, however, been brought together, and certain conclusions may be drawn from it. The first is that a number of experiments have been made in the preservation of industrial peace. The second is that, in spite of a popular impression to the contrary, and of some failures, those experiments have been attended by a considerable measure of success. The new unionism is in this connection less ominous than the 'demarcation disputes' which have lately risen into prominence. The third conclusion is that the conditions of success are now ascertained, and consist in organisation. The commissioners express this opinion in definite language, although they enter a caution against hasty inference from it, and the secretary's report of the position in other countries shows that an absence of conciliatory methods accompanies immaturity of organisation. The fourth and last conclusion is that little room is left for the intervention of the State, save in the *rôle* of pacific counsellor. This conclusion is endorsed by the minority, in spite of their collectivist tendencies, and various difficulties attach to the substitution of the compulsory legal authority of the State for the moral influence of voluntary organisation. The report of the Commission may seem petty and impotent when contrasted with the vastness of the inquiry, but probably it will recommend itself to sober common-sense.

5. *On Women's Industries.* *By* Miss MAITLAND.

6. *On Girl Life in an Industrial Centre.*[1] *By* Miss KENWARD.

Subject of woman's work too large and complicated to allow of sweeping conclusions from an inquiry limited, as the present one, to a particular industrial centre.

The centre chosen is the district of the non-textile industries at Birmingham. Principal trades: Brass, steel, iron, tubes, guns, ammunition, jewellery, screws, nails, steel pens, bedsteads, chandeliers.

The number of registered factories is three thousand, and, roughly, six men employed to every woman. Result: Girls' labour market overstocked and competition keen. The trade depression of late years makes this increasingly felt. This condition is aggravated by growing aversion of girls to domestic service. Reasons for this aversion are the unbusinesslike relations of the latter; the cry for liberty, which is greater than the cry for wages. This spirit of independence of thought and control is fostered by the spread of education. The remedy for equalising the factory and service markets is to place the two on an equal footing as regards contract and inspection.

Conditions of service are more desirable than conditions of the factory, because of the evils produced by competition such as (*a*) starvation wages, which oblige girls to eke out a livelihood dishonestly; (*b*) frauds and deceits practised by women to obtain and keep work. Suggestions:—

Possibility of labour agencies. Inspection in warehouses unattached to factories, and in shops and laundries.

Position of centre as regards—

(I) *Wages.*—For unskilled labour 7*s.*, 8*s.*, 9*s.* a week, as a rule; 10*s.* a week high. Girls of fifteen and sixteen earn 3*s.* 6*d.* to 4*s.* 6*d.* a week. Centre probably stands midway as compared with Lancashire, Wales, Ireland.

(II) *Health.*—Lowered vitality rather than actual disease; phthisis and anæmia common; epileptic and fainting seizures also prevalent. Specially unhealthy work; lacquering and enamelling of iron plates. Precautions against lead poisoning and their disuse.

(III) *The Moral Tone of Factory Life.*—Effect of married women in factories bad. Illustrations, betting, drinking, and immorality are due in large measure to their influence. Effect of 'clubs,' 'rum teas,' 'free-and-easies' on a girl's life. Position of girl in home as semi-lodger, monotony, and long hours of factory tend in the same direction, producing a desire for unrestrained licence.

Improvements possible partly through legislation, combination, and partly through the raising of relations between employer and employed from mere cash ones.

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[1] Published *in extenso* in *Women Workers*, September 1894. Birmingham.

Conclusion: That in the mass of *unskilled* labour in such centres the tendency is towards a low standard of morality, and the conditions of industrial life for this class of girls are in greater need of reform than the present conditions of domestic service.

SATURDAY, AUGUST 11.

The following Papers were read:—

1. *Statistics of Comparative General and Old-age Pauperism in England and Wales,* 1831 *to* 1891. *By* C. S. LOCH.

1. Material available. Plan of investigation. The method of comparison adopted.

2. The issues to be settled:—

(1) Is pauperism on the increase (*a*) in regard to children, (*b*) in regard to the able-bodied, (*c*) in regard to the not able-bodied, including the aged and infirm?
(2) Is there less continuous pauperism, but more casual and intermittent pauperism?
(3) How far are local habit and race instinct a barrier against pauperism?
(4) How far is pauperism influenced by administration?
(5) Does the rule hold good generally that reduction of outdoor relief reduces pauperism, and that this reduction is accompanied by a slight, but by no means corresponding, increase in indoor relief?
(6) Is there reason to believe that the forces now at work, if allowed fair play, would reduce pauperism and State maintenance to a minimum?
(7) Can we ascertain what standard of pauperism may fairly be expected to prevail in any circumstances in the community?

3. The pauperism of the union as shown by an analysis of cases in some metropolitan and other unions: its character; how far it is transitory, how far permanent; how it is relieved.

4. The pauperism of England and Wales, past and present: in regard to children, the able-bodied, and the not able-bodied.

5. The pauperism of the union counties considered historically:—

(1) The pauperism of the counties in the year 1831, as shown by financial statistics.
(2) The pauperism of the counties, recorded and comparative, as shown in the returns for the Lady Day quarter 1840 to 1846.
(3) The general pauperism of the counties, recorded and comparative, by January 1 returns: 1861, 1871, 1881, 1891 (sketch maps of comparative pauperism for 1862–71, 1872–81, and 1882–91 were exhibited). In these and other statistics in this pauper vagrants and lunatics are omitted, unless their inclusion is mentioned.
(4) The not able-bodied and old-age pauperism of the counties.

6. The pauperism of the unions of forty-one large towns, including London, shown on the comparative method, 1861 to 1891. The relation of London and the large towns to the country generally in regard to pauperism.

7. A comparison of the year 1881, based on Mr. Hollond's return, with the year 1892, based on Mr. Ritchie's return, showing the decrease in the volume of pauperism in the year.

8. The pauperism due to old age: its true measure and amount.

9. The present restraints on pauperism.

10. The finances of Poor Law administration. On what heads and in what

counties there has been an increase. The relation of London to the larger towns, of these to the rest of the country in respect of expenditure on poor relief.

11. Conclusions on the issues raised.

2. *Proposals for an Agreement on the Terms 'Rent' and 'Interest.'*
By C. S. DEVAS.

Need of agreement in terminology to prevent fruitless discussion.—Changes and uncertainty from the time of Adam Smith on the classification of incomes briefly illustrated.—One reason for this is the abstraction that separates *land* from *capital*.—Economic authorities for making only two requisities of production, persons and things, or labour and capital.—Professor Böhm Bawerk's *five reasons* for separating land from capital answered: First, that land is immovable, capital mostly movable. Secondly, that land is the gift of Nature, capital the result of labour (Böhm Bawerk's definition of capital amended.—Dr. Sidgwick's wide view of capital does not affect the present issue).—Thirdly, that land cannot be increased, while capital can (universal application of the law of diminishing returns).—Fourthly, that the social and economic position of the landowner is quite different from that of the capitalist.—Fifthly, that under certain circumstances land-rent rises while interest falls. *Conclusion*, that the separation of land from capital is logically indefensible, historically misleading, and practically inconvenient.—Classification of incomes into rewards of labour, returns from capital, and a combination of the two.—Objection on there being no place for the doctrine of rent.—Professor Marshall on that doctrine.—Character of differential gains above those of the *marginal pair* in a market.—The so-called rent of land one out of many such differential gains.—Need of one term for all such gains, and of another term for all receipts from property.—Advantage of using the term *rent* for all such receipts, and *rentier* for their receiver.—Difficulty from the frequent use of *economic rent* for differential gains and of *interest* for receipts from property.—Need of coming to an agreement.—The strange misunderstanding, for example, that the economic doctrine of the Fathers, Canonists, and Theologians is socialistic could never have arisen had our terms been clear.

3. *On the Economic Results of the Black Death in Italy.*
By MAXIME KOVALEVSKY.

The pestilence of 1348–49 produced all over Europe the economical results it had in England. The depopulation of Europe brought forward the labour question. For the first time it had to be treated, on a large scale, as a question of almost international importance. Without any previous agreement the Governments of France, Aragon and Castella, as well as the political authorities of independent or semi-dependent cities of Italy and the German Empire, issued ordinances prohibiting idleness, enforcing the obligation of farmers to pay rents, and regulating the wages of labourers and working men. The fall of serfdom, which was almost accomplished in Italy at the end of the thirteenth century (Piedmont and Frioul excepted), created here centuries before they are found in France or Germany a large class of free farmers (Mezzeria di Toscana, i terziafori di Lombardia, &c.) and free working men. A regulation of wages appears already in the thirteenth century. Pisa, Mantua, Nice, some Sicilian municipalities, tried to establish a legal standard of wages. Their example was followed at the end of the pestilence by almost every city of Middle Italy. Florence, Sienna, Orvieto, Todi, &c., issued orders and statutes against the enhancement of wages, either according to the labourers and artisans the right to a supplementary pay, not surpassing the third of the wages they got before the pestilence, or totally refusing any increase of remuneration. Venice alone tried to achieve the same end—the lowering of wages—by the way of liberty. Its example was followed by dependent municipalities, such as Treviso or Ragusa. All encouraged emigration, according great facilities to new settlers, admitting them to the crafts, guilds, and to the exercise of commerce. Their endeavours were successful. At the end of the century, notwithstanding several new appearances of the plague, the Republic of St. Mark was repopulated, and the wages fell.

MONDAY, AUGUST 13.

The following Papers were read:—

1. *On Inequality of Local Rates: its Extent, Causes, and Consequences.*
By EDWIN CANNAN, *M.A.*

The intricacy of the system under which money raised by one local authority is usually expended by several others, the immense number of different areas created by the overlapping of the various kinds of districts, and the inadequacy of the published returns, make it impossible to give any very comprehensive statistics as to the inequality of rates in England. In the small county of Oxfordshire the number of districts governed by different combinations of rate-raising authorities exceeds sixty, and the sum of the rates varies from about 1*s.* 6*d.* to about 6*s.* 6*d.*, the highest and the lowest rated districts being within ten miles of each other. In the whole of England and Wales the lowest rated district pays about 1*s.*, and the highest over 8*s.*

The chief causes of inequality of rates may be classified as follows:—

(1) Unequal returns from investments and unequal repayments of debt.
(2) Unequal services performed for self-supporting persons by the local authorities.
(3) Inequalities of situation and circumstances which cause the same services to cost unequal amounts.
(4) Unequal endowments.
(5) Unequal voluntary liberality.
(6) Unequal cost of certain charges imposed by law on localities, although they do not increase the advantages of a locality as a place of business or residence for self-supporting persons.
(7) Inequalities of competence or honesty on the part of the authorities.

The consequences, considered from the point of view of just distribution, are good so far as the inequalities are occasioned by causes 1, 2, 3, and 7, bad so far as they are occasioned by cause 6, and haphazard so far as they are occasioned by causes 4 and 5. Considered from the point of view of maximum productiveness of industry, the consequences of the inequalities are good so far as they are occasioned by causes 1, 2, 3, and 7, and bad so far as they are occasioned by causes 4, 5, and 6.

2. *A Few Remarks on Fifty Years' Accounts of the Bank of England.*
By A. W. FLUX, *M.A.*

The completion of fifty years of the operation of the present Bank Charter, coinciding as it does with the bicentenary of the Bank, seems a suitable occasion for the study of the accounts.

The *active note-circulation* of England and Wales is now, owing to the operation of the Act of 1844, almost entirely in the hands of the Bank of England. The Bank of England has fewer notes in circulation than fifteen years ago, and the total active note-circulation of the country is hardly greater now than when the Act was passed. The bank-note is, in fact, used in business to a much less extent than formerly, other means of exchange and remittance, such as cheques, having been substituted for it. The annual variation of the quantity of notes in circulation has, of recent years, been much more uniform than it formerly was. The amount of the variation is two and a half to three millions in a total of about twenty-five millions. The year 1869 alone shows a less difference than two millions between the minimum and maximum. There were very large variations at the time of the 1866 panic, and in the years 1878-9. In the latter case the variation consisted of a greatly increased circulation in 1878, which did not begin to return to the normal level till 1879 was far advanced. Taking three millions as the ordinary variation in a year, the circulation in these years varied in excess of the normal by 2·6 and 3·8 millions respectively. It seems rather unlikely that such large increases of the normal variation should be due to the ordinary use of the bank-note for making cash payments. Probably a considerable proportion of the registered increase was merely an addition to the till-money held by bankers, and was never really in active circulation. How much of the ordinary active circulation, so-called, is of the same nature there are no means of telling.

The *other deposits* have largely increased. Taking the half-century in five periods of ten years, the average amount of other deposits in each period has been about eleven, thirteen, eighteen, twenty-four, and twenty-seven and a half millions. The considerable increase in the month of April, which was so marked during the decennium 1844–54 that the maximum of the year was reached in the middle of that month, has now almost vanished. The annual variation is less in proportion to the total than formerly, having then been about 20 per cent. on either side the average, while during the last decade it averaged hardly more than 15 per cent. What proportion of the increased deposits are bankers' balances is not known, it being nearly twenty years since the Bank ceased to supply this useful piece of information. The fluctuations of other deposits have, during the last ten years, been less steady than formerly.

The *public deposits* vary in a manner markedly different from that of fifty years ago. Then there was a regular quarterly ebb and flow not differing much from quarter to quarter. The changes in the collection of the taxes have led to the increase of the March maximum and the progressive decrease of the others. This makes the maximum of total deposits fall at the end of March, in spite of the decrease of the importance of the spring variation of other deposits.

Taking next the *coin and bullion*, we notice that this item shows more frequent variation than formerly. Its amount has increased by little more than one-half as compared with half a century ago, and the average of the last ten years is nearly 10 per cent. less than that of the preceding ten years. No information is generally afforded as to the proportions between the coin and bullion held, or as to the amount of silver coin in the banking department.

The *reserve* is the item of the account which attracts greatest attention. The annual variation for the last ten years has averaged about 25 per cent. on either side of the mean, while in the ten years after 1844 it was nearly 30 per cent. The average reserve during these two decades has been about fifteen and nine millions respectively. As the total deposits have doubled, while that part of them which reflects most closely the business of the country, the 'other deposits,' has increased by 150 per cent., the increase of reserve seems inadequate. For the three years 1891–2–3 the reserve has averaged sixteen millions, while the *other deposits* have averaged nearly thirty-two millions.

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3. *On the 'Economic Heresies' of the London County Council.*
By SIDNEY WEBB, *LL.B., L.C.C.*

The Council has been intelligently criticised, from an economic point of view, mainly on three grounds: (*a*) its adoption of a 'standard' and 'moral minimum' of wages, and consequent refusal to take advantage of the fiercest competition in reducing the price of labour; (*b*) its attempt to ensure that all contractors executing work for the Council should adopt the same policy; and (*c*) its supersession of the contractor, wherever possible, by the direct employment of workmen under salaried management.

The facts and statistics given in the paper show precisely what has been done in these respects, together with such economic results as can already be discerned. It is contended that the Council's action is warranted by all administrative experience, and that it has the support of economic science. It is suggested that the 'economic heresy' is with the opponents of this policy. The experience of the National Government, other local authorities, and private customers is adduced in support of the policy of insisting that contractors should act on a like principle. The contractor's tendency, if let alone, is to seek his profits in a diminution, not necessarily of the cost of production to the community, but of the expenses of production to himself. The lesson of economic science is that it is advantageous to the community that there should be a constant upward shifting of the plane on which competition works (*cf.* the Factory, Sanitary, and Adulteration Acts), and especially that its pressure should be taken off the standard of life, and placed on the brains of the administrators and directors of industry.

The supersession of the contractor, or *entrepreneur*, by direct employment under salaried management is shown to be part of a widespread tendency, common not only to other governing bodies, but also to large industrial undertakings of every kind. This 'integration of processes' can be traced in all important undertakings. So far as the change of policy can be assigned to a particular date, it appears to have taken place between 1875 and 1885. Economic advantage in this suppression of the subsidiary *entrepreneur*, or contractor, is found (*a*) in saving middleman profit; (*b*) in saving expense of incessant checking of the quality of his product; and (*c*) in increased convenience of having all parts of work done under direct control. The London County Council, in doing as much as possible of its own work, is thus merely conforming to an industrial tendency, strongly marked, not only in other local governing bodies, but also throughout the industrial world. The elimination of the contractor may or may not be economic heresy, but the business history of England during the past twenty years indicates that it is industrial orthodoxy. Formerly the best business management was held to be that which managed least; nowadays it is that which can safely and efficiently administer most.

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4. *On Co-operation in Agriculture.* *By* HAROLD MOORE.

It was pointed out that many systems of working land in order to give the workers the profits earned by them had been tried. These were divided into four classes, viz., communal farming, being those cases where the co-operators worked on equal terms for the benefit of the community, as tried at Ratalime in Ireland; co-operative tenancy, where the co-operators jointly took the position of ordinary tenants, as at Assington in Suffolk, and elsewhere; profit-sharing, where the labourers had some share in the management, as tried by Lord Spencer in Northamptonshire and by Mr. Bolton King in Warwickshire; and profit-sharing as a voluntary arrangement made by landowners working their own property, as carried out by Mr. Albert Grey in Northumberland and by others. The reasons why the first three systems were not likely to be successful were pointed out, and it was urged that for co-operation in agriculture to succeed it was necessary that distinct individual interest should be combined with those advantages which co-operation would give. This it was claimed could be done by the establishment of the intending co-operators on one farm, giving to each one a particular portion of the land on perpetual lease or other secure tenure, and securing for their general benefit agricultural credit banks, farm factories, and other means of co-operation which would assist in working the land and realising that portion of the produce which would not be consumed. Instances were then given of this system of co-operation which is now being introduced with useful results, it being finally urged that this was the best system by which those agricultural labourers now in want of regular employment, owing to the existing condition of agriculture, would be best assisted to secure maintenance for themselves and families.

TUESDAY, AUGUST 14.

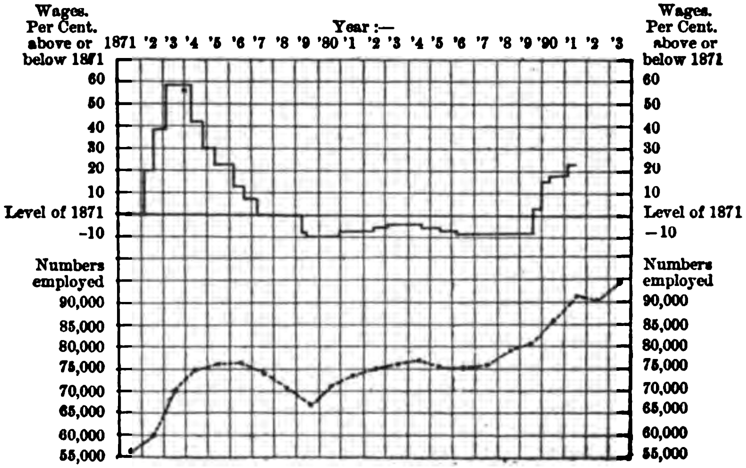
The following Reports and Papers were read:—

1. *Report of the Committee on Methods of Economic Training in this and other Countries.*—See Reports, p. 365.

2. *Report of the Committee on Teaching of Science in Elementary Schools.*—See Reports, p. 359.

3. *On the Relation between Wages and the Numbers employed in the Coal-mining Industry. By* R. H. Hooker, *M.A.*

The influence of wages in attracting labour to an industry is best shown by means of a diagram, and the industry concerning which we possess the most trustworthy statistics of wages and of the numbers employed over a series of years is undoubtedly coal mining. The data concerning this occupation have accordingly been plotted on the annexed diagram, in which the upper (continuous) line represents the course of wages in 1871–91 in the county of Durham (according to the evidence of Mr. L. Wood before the Labour Commission [1]), while the lower (dotted) line shows the number of persons employed in coal mining in the same county (taken from the annual reports of the mining inspectors). The wages are expressed in percentages above or below the rate paid in 1871.



The correspondence of the two curves is very apparent, and, judging by the magnitude of the fluctuations, it would seem that the variations in the number of the *employés* must be attributed almost entirely to the changes in wages. Especially the very large increase of miners in 1872–74 and 1889–91 can hardly be ascribed to any other cause than to the attraction of the great rise in wages at those periods. It must be remembered that the coal-mining industry is in many respects peculiar, the organisation of the men is very complete, and the principle of the sliding scale is everywhere in force, even in those districts where a scale does not actually determine the wages. These latter being then dependent on prices, employers cannot lower their rate of pay when the supply of labour is unusually large, nor can they raise the remuneration unless there is a corresponding change in the price of coal. It would seem, then, that the numbers depend on the wages. It does not follow that this condition prevails in every occupation, but it is probable that, according as the organisation of the men in any industry is more complete, there is a greater tendency in that industry for the numbers employed to follow the wages.

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[1] *Parl. Paper*, C. 6,708, iv.

4. *Popular Attitude towards Economics.* *By* Rev. L. R. Phelps, *M.A.*

Economics once a rule of conduct, now either contemned or patronised.
History of the change of opinion.
Reasons for the change:—

1. On the part of economists:
   Desertion of the *à priori* method.
   Attempts to generalise from an existing state of things.
   Tendency to be content with an historical explanation of facts.
2. On the part of the public:
   Dislike of exercise of reasoning powers.
   Tendency to substitute an appeal to sentiment for appeal to reason.
   Impatience of slow growths.

Possible remedies:—

1. A narrowing and defining of the field of economics.
2. Education of the public by experience.

5. *On the Relation between Wages, Hours, and Productivity of Labour.*
By J. A. Hobson, *M.A.*

Progressive wages. Operative upon different elements of industrial efficiency. Economic limits in several kinds of work. (1) The navvy; (2) the agricultural labourer; (3) the textile worker. Curves of productivity in relation to rising wages.

Progressive leisure: Two classes of effects: (1) Compression and intensification of effort per unit time; (2) improved quality of labour by utilisation of leisure. Curves of productivity as affected by (1) objective economic conditions of industry; (2) race, class, climatic and other conditions affecting labour. Relativity of the policy of a short working day.

Combined action of rising wages and reduced hours of labour. Interdependency of the two. Complex character of the curve expressing the joint action. The assimilation of fresh increments of wages and leisure.

Progressive wages and leisure dependent upon advancement of industrial arts. Power of the former to direct and stimulate the latter. Limits to this power. Comparison of advanced and backward trades in respect to the progressive policy of wages and hours. Inductive arguments for the Eight Hours' Day. How far valid? General summary of relations of wages, hours, and productivity.

Section G.—MECHANICAL SCIENCE.

President of the Section—Professor A. B. W. Kennedy, LL.D., F.R.S., M.Inst.C.E.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

The Critical Side of Mechanical Training.

While there is no place in the kingdom more suitable for a meeting of the British Association than Oxford, and certainly no place in which it is more delightful for the members to meet, it is yet to be admitted that there are few places which have much less in common with the special work of Section G. Nominally devoted to 'Mechanical Science,' the Section has for many years specially dealt with those branches of applied mechanical science which constitute the business of the engineer—to quote the well-known words of the Royal Charter, 'the art of directing the great sources of power in Nature for the use and convenience of man.' The association of this ancient and learned city with boilers and chimneys, with the noise and racket of ordinary mechanical work, seems an incongruity. Even the harmless necessary railway station is kept as far away as possible, and the very river flows with a quiet dignity which seems to shut out the thought of anything more mechanical than the most ancient and futile of water-wheels.

Naturally enough these considerations did not tend to make more easy the choice of a subject for this address, and I have come very near to agreement with a recent critic in the opinion that presidential addresses are, in fact, almost immoral in the nature of things and fit only to be abolished. Finally, I decided upon taking up my present subject, as being one in which the academic rather than the technical side of our work comes to the front, while at the same time it does not lead me out of lines in which I have been able, in past years, to work myself. It is now twenty years since I first took any active part in the scientific training of engineers, and five since I ceased to do so. I have often wished that I may have been at all as successful in teaching others at University College as I was, at the same time, in teaching myself. And since I have ceased to teach I seem to have been spending my time in finding out how much better I could now do it than was possible when I was actually engaged in it. This may be pure imagination on my part; there is nothing more easy, as we all know, than to suppose that we know best how to do the things that other people do, and not the things we have to do ourselves. Indeed, I understand that this is the recognised attitude of the really superior critic. If, however, in anything which I have to say, it should seem that I am finding fault with what is now being done, I may at least point out that most of all I am finding fault with myself for not having done right when I had the opportunity—an opportunity which can now never recur. Indeed, instead of the decorous and unobtrusive heading which I have given to this address, I might have indicated its general lines almost as truly if I had entitled it 'The Regrets of an Emeritus

Professor'—a name which, on a suitable binding, might even have secured it a sale at the railway bookstalls.

I know well—too well—that in the present congested state of the engineering profession there are many of us who do not like to hear the word 'training' mentioned at all. It seems to mean merely the preparation of more lads to struggle for a share of work that is even now insufficient to go round. There is no doubt much to be said for this point of view. But against it one must remember that all other professions are equally full, and that, after all, lads must do something. The fault is surely that there are too many lads! If our population is really to go on increasing as rapidly as at present—the benefits of which Sections D, E, and F might have a joint meeting to discuss, if not to discover—it is inevitable that demands should come for more and more complete professional preparation. The man of exceptional parts will come to the front under any conditions, training or no training, in the future as in the past. But for ordinary men—that is, for 99 per cent. of us—it is essential that no advantage should be given to a rival in the fierce competition of life, and for them therefore it is of an importance hardly to be exaggerated to obtain the most complete and perfect training possible. At the same time, and on purely general grounds, it can hardly be denied that to raise the standard of our profession is indirectly to confer a benefit on the whole community. I hope, therefore, that in making certain suggestions about the training of engineers, it will not be thought that I am desirous of increasing their number, which is really an end as far as possible from my own wishes. Whether the number increases or stands still or falls off, it is of importance from every point of view that those who come forward should be as well prepared as possible. And even the most conservative of us are compelled to recognise that the standard required in engineers' offices now is enormously higher than it was thirty years ago. This may truly be either the cause or the effects of improved training, but in either case it has made the training itself a necessity.

The particular aspect of mechanical training of which I wish to speak is its critical side. I do not know how a man should be trained to be an inventor. I would not tell anyone if I did! To be a creator in mechanical matters—which, however, is a quite different thing—is a faculty given only to a very few, and with them it is 'born, not made.' Many of us, however, without being either inventors or creators, have sufficient natural aptitude or inclination towards things mechanical to form a basis for the trainer or educator to work on, with some hope that he may be of service. About the sciences which should be taught to such men, or the methods of teaching them, about the extent and nature of their experience in shops or on works, I do not intend to speak. I shall confine myself to one aspect of the training only, an aspect which is perhaps not always sufficiently clearly kept in view—the aspect which I have just called the critical side of mechanical training.

An engineer is a man who is continually being called upon to make up his mind. It may be only as to the size of a bolt; it may be as to the type of a Forth Bridge; it may be as to the method of lighting a city; or only as to the details of a fire-grate. But, whatever it is, once it is settled it is decided irrevocably—it is translated into steel and iron and copper, and cannot be revoked by an Act passed in another session. The time given him in which to decide may be a day, or a month, or a year, but in any and every case (so far as my own experience goes) it is about one-tenth part of the time which he would like to have. It is only in rare cases that the decision is obvious—most often there are more courses open than even the most facile politician ever dreamt of. The matters are too complex to be dealt with mathematically or even physically; even if they were not, there are few engineers who would have the special capacity to handle them. Moreover, their solutions are seldom 'unique.' From this point of view, the whole use of college training, of workshop practice, of practical experience, is to provide the engineer later on with the means of critically examining each question as it comes up, of reviewing systematically the pros and cons of each method of dealing with it, of coming finally, rapidly, and positively to some defensible decision, which may then be irrevocably carried out.

In the case of a problem in pure mathematics or physics, where only one right solution can exist, that solution is arrived at by the help of a thorough knowledge of the science in question—there is little room for the critical faculty except as to method—the result is either right or wrong. With our work, on the other hand, solutions of all problems except the very simplest—in other words, decisions on all points which present themselves—can be arrived at only by a process of criticism applied to the problems, to their statement, to their condition, to all their many possible solutions. The development of the necessary critical faculty should be one of the chief aims of every teacher and every student.

A scientific training cannot make a man an engineer. Perhaps it is impossible for anything to make a man an engineer unless he has grown that way from the beginning! But a scientific training may make him, or at least give him the possibility of making himself, a critic.

In the vigorous attempts which have been made to specialise the education of engineers very early, I am afraid that the idea of teaching *subjects* is sometimes too prominent, to the neglect of matters less obviously useful. It is, of course, one thing to know a subject from the examination point of view, and quite another to be able to think about it, and still another to be able to write about it. In particular, I have often regretted to find how little attention has been given to a matter which perhaps may be called literary rather than scientific, but which is all-important in criticism, I mean to the power of expression. It is not easy to overrate the importance to the engineer, as to other folk, of the power of saying clearly what he means, and of saying just what he means. I do not mean only of doing this for its own sake, but because if a man cannot say or write clearly what he means it is improbable that he can *think* clearly. By the power of expression I do not mean, of course, the mere power of speaking fluently in public, a thing which appears physically impossible to some people; I mean rather the power of expression in writing, which carries with it clearness and consecutiveness of thought. It is difficult to know how this matter can be taught, but at least it can be insisted upon probably to a much greater extent than is commonly the case. A man requires to see clearly not only the exact thing which he wants to say, but the whole environment of that thing as it appears to him. Not only this, but he must see the whole environment of the same thing as it appears to the persons for whom he is writing, or to whom he is speaking. He has to see what they know about the matter, what they think, and what they think they know, and if he wishes to be really understood has got to do much more than merely write the thing he means. He has carefully to unwrite, if I may use the expression, the various things that other people will be certain to think that he means. For after all the great majority of people are very careless listeners and readers, and it is not for the small minority who are really exact in these matters that one has to write. Moreover, it is a great help to clearness of thought and expression to keep before one always an ideal audience of people who will certainly misunderstand every single sentence about which any misunderstanding is in any way possible, and some others as well.

In attempting to think out or to discuss any question, whether it be technical or non-technical, in fact, as long only as it is non-political, the first necessity is probably a knowledge of the question itself, and not only this, but also a proper understanding of its whole environment. This knowledge must be of such a kind as to distinguish what parts of it are important, what parts of it are unimportant, what parts can be described in two sentences, and what others may require as many paragraphs; what parts affect the result but little, however large they seem; and which ones must be considered vital, although their very existence is difficult to discover. The faculty which enables a man to handle his knowledge in this fashion may be summed up in the single expression 'sense of proportion.' Moreover, the knowledge, to be of real value, must be as totally free from prejudices and prepossessions as in the most rigorous branch of pure science, and as thoroughly imbued with a healthy spirit of scepticism.

One is accustomed to think of engineering work as mainly constructive. But after all it is quite as much critical. In almost every department of mechanical work there are half a dozen ways of solving any particular problem. In some fashion or other the engineer must be able to judge between these various methods; methods which are often very much alike, but each of which may possess certain particular advantages and certain particular drawbacks. The arithmetical criticism which merely counts the advantages and the drawbacks, and puts an equal number of the one against an equal number of the other, is common enough, but obviously useless. The very first necessity to the critic is that he should have what I have just called the sense of proportion, a sense which will enable him to distinguish mere academical objections from serious practical difficulties, which shall enable him to balance twenty advantages which can be enumerated on paper by one serious drawback which will exist in fact, which will enable him in fact to place molehills of experience against mountains of talk. It is perhaps a doubtful point how far this sense of proportion can be taught at all. No doubt it can only be built up upon some natural basis. I am sure that in engineering we all know men whose judgment as to whether it was advisable to take a particular course we would accept implicitly, because we know that it is based on large general criticism, in spite of the most elaborate and specious arguments against it set down on paper. Any third-year student—not to go still further back—can criticise perfectly along certain very narrow lines, just as anyone can learn the rules of harmony and can write something in accordance with them which purports to be music. But after all the music may be music only in name, and the criticism may not be worth the paper it is written upon, however formal it may appear to be, unless the writer is thoroughly imbued with a sense of the proportionate value of the different points which he makes. To take the commonest possible case, I dare say we have all of us heard certain methods, mechanical, chemical, or other, stigmatised as totally wrong and absolutely useless because they contain certain easily provable errors. I am sure, too, that most of us could give illustrations of cases in which this has been said with the very greatest dogmatism when the errors of the impugned method are not one-tenth part as great as the equally unavoidable errors of observation in the most perfect method.

Probably the best special education in proportion which a man can have is a course of quantitative experimental work. I say *quantitative* with emphasis, as meaning something much more than mere qualitative work. Here, I think, comes in the usefulness of the engineering laboratory. We require that the training should be not only in absolute measurement, but in relative measurement, the latter being quite as important as the former. Many kinds of measurements stand more or less upon a level as a training of the faculties of observation in themselves, but no single kind of measurement is sufficient as a training in proportion. A year spent in calibrating thermometers or galvanometers might make an exceedingly accurate observer in a particular line, but it would not give the observer a knowledge of what even constituted accuracy in other directions; for accuracy is a relative and not an absolute term. In most engineering matters the conditions are, unfortunately, of a most complex kind; so complex that our problems are incapable of any solution sufficiently exact to satisfy the mathematician or physicist. The temptation to treat these problems as the mathematician treats those with which he deals—namely, to alter the assumed conditions in order to get an exact solution—is a very strong one. I am afraid it is most strong often in those engineers who are the best mathematicians. It is a temptation, however, steadily to be resisted. We must assume our conditions to be what they actually are, and not what we should like them to be; and if we cannot obtain an exact solution of our problem with its actual conditions, so much the worse for us, not so much the worse for the conditions. Our first duty is generally to find out the conditions; if they are disadvantageous (in fact I mean, and not merely in the problem), to alter them if they can be altered, but not to ignore them because they are inconvenient. We have then to find out the extent to which the known conditions permit any exactness of solution at all, and, finally, we have to keep this in view as a measurement of the highest accuracy which is attainable. To work out certain branches of the problem with such minuteness as to give us apparently very much greater accuracy than this is not only useless, but is apt to be positively misleading, as giving an impression of an accuracy which has no real existence.

The relative value of accuracy in different sets of observations is in itself a matter in which a sense of proportion is wanted, and often very badly wanted. Where one has to measure half a dozen things of which two are very easily measured and the remaining four are only measurable with great difficulty, it is only human nature that we should spend our energies on getting extremely accurate results with the first two and roughly do our best with the others. It is very difficult under such circumstances to remember that the accuracy of the whole is not the accuracy of the best part of our work, but of the worst.

The extraordinary effect of a want of sense of proportion is nowhere better shown than in the absurd statements which are constantly made as to technical matters in public prospectuses, and the still more absurd statements made in those very numerous documents of a similar kind of which some of us see a great many, but which do not finally emerge into public view. Fortunes are apparently to be made by inventions which, although doubtless ingenious, yet only concern one way of doing a thing which could be done equally well in half a dozen other ways. Every one is expected to run after a piece of apparatus which is to save 50 per cent. of something, the total cost of that something, however, being so very small that nobody cares to save in it at all. I need hardly mention the all too common case where a contemplated saving of 10 per cent. in the cost of a material works out yearly to an amount much more than equal to the whole cost of the original article.

I believe that experimental work in an engineering laboratory can educate this critical sense of proportion very admirably in a number of ways. In the first place, it directs quantitative work into very varied channels, and not along one particular line. Secondly, it compels the observer to combine a number of measurements in such a way that the relative importance of accuracy in each can be seen. In the case of an engine trial, for instance, the combined results are affected by the accuracy of measurements of the dimensions of the machine, by the apparatus and methods used for measuring the water, by the indicator, and by its springs, by the speed counter, by the thermometers, and so on. An error of 1 per cent. in counting the revolutions is just as important as an error of 1 per cent. in measuring the water, or in measuring the mean pressure. I am afraid that one could point to a good many cases in which this has been more or less forgotten. Then, by making a series of measurements all in absolute quantities, the relative importance of each quantity to the desired total result can be seen. Thus it will be found that changes in certain quantities affect the total result to a very small extent, while changes in others affect it very largely, so that not only is the accuracy with which different quantities can be determined very different, but also the same degree of accuracy is of very different importance according to the particular quantity to which it refers. Once it is found that a final result is exceedingly little affected by a particular set of changes, it ceases to be of importance to measure or observe those changes in any extremely minute way, and of course the reverse holds equally good. Finally, and this perhaps is the most important matter of all, measurements in such a laboratory are made to a great extent under the complicated conditions under which the actual final result has to be obtained in practical work. They are not made under the conditions which insure the greatest individual accuracy of each result.

It will be seen that throughout, but particularly in the two last points which I have mentioned, the work of an engineering laboratory is in intention and in essence different from that of a physical laboratory. The aim of the latter is to make its problems as simple as possible, to eliminate all disturbing elements or influences, and to obtain finally a result which possesses the highest degree of absolute accuracy. In most physical investigations the result aimed at is one in which practically absolute accuracy is attainable, although attainable only if infinite pains be taken to get it. It is the business of the physicist to control and modify his conditions, and to use only those which permit of the desired degree of accuracy being reached. In such investigations it sometimes becomes almost immoral to think of one condition as less important than another. Every disturbing condition must be either eliminated or completely allowed for. That method of making the experiment is the best which ensures the greatest possible accuracy in every part of the result. The business of the engineer, on the other hand, is to deal with physical problems under conditions which he can only very partially control, and the conditions are a part of his problem. He does not, for instance, experiment with a steam engine so made that it can work with a Carnot cycle. It is in the nature of the case that he must experiment with a much less perfect machine. In burning fuel he does not use apparatus specially made to absorb the whole heat of combustion, but in the nature of the case has to investigate the behaviour of apparatus in which a very large part of that heat is unavoidably wasted. So one might go on through an immense number of instances. Perhaps the whole matter may best be summed up by saying that in a physical laboratory the conditions of each experiment are under the control of the experimenter, and are subservient to the experiment itself. In an engineering laboratory the conditions form part of the experiment. However much more difficult or complicated they render it, they still unavoidably form part of it—an experiment under any other conditions, or with those conditions removed, would *ipso facto* be irrelevant.

A critical training in matters mechanical is, however, only too similar to the celebrated training of the Mississippi pilot which so nearly broke the heart of Mr. Mark Twain. Whenever the whole matter seems to be completely mastered from one point of view, it is only to find, with a little more experience, that from another point of view everything looks different, and the whole critique has to be started afresh. Machines cannot be finally criticised—that is to say, they cannot be pronounced good or bad—simply from results measurable in a laboratory. One wishes to use steam plant, for instance, by which as little coal shall be burnt as possible. But clearly it would be worth while to waste a certain amount of coal if a less economical machine would allow a larger saving in the cost of repairs. Or it might be worth while to use a machine in which a certain amount of extra power was obviously employed, if only by means of such a machine the cost of attendance could be measurably reduced. In fact, what may be summed up in the phrase the 'worth-whileness' of economies, is in itself a matter on which a whole paper might be written. Unfortunately, the latter points which I have mentioned are just such as cannot easily be measured in laboratory work, or, indeed, in any other way whatever, except by actually using the apparatus in question. All that can be said is that a careful training in the critical measurement of comparatively simple points fits a man more than anything else to gauge accurately the importance of such other matters as I have mentioned. No doubt there are many men in whom the critical faculty is insufficiently developed to allow them ever to be of use in these matters, but to those who are intellectually capable of the 'higher criticism' it must be, I think, of inestimable benefit to have had a systematic training in the lower.

Is there, then, any general standpoint from which mechanical criticism can be directed? Certain points are obvious, but probably the whole matter cannot easily be generalised. A city has to be supplied with water; there are three requisites: that the water should be of proper quality, of sufficient quantity, and that it should be brought in at a reasonable cost. But in such a case the first two are so enormously more important than the third, that the ideal is comparatively simple (of course, this is quite a different thing from being simply reached). A city has to be supplied with electric light: the essential conditions are similar. But in this case there are so many qualities which are equally proper, and there are so many different ways of bringing it in in sufficient quantity, that the third point—namely, the cost—becomes especially important. A factory has to be driven by steam power: the amount of power that is wanted can be produced by so many different types of engine and boiler—all capable of approximately equal economy, and all claiming equal freedom from breakdowns—that the choice is a peculiarly difficult one from the critical point of view.

It seems almost impossible that a criticism on any one basis could meet all the three cases which I have supposed, unless that basis were that the thing supplied should be the absolutely fittest, having regard to all the conditions of each case and the relative importance of each condition. Possibly in all cases we could get at some generalisation which would show us which was the absolutely fittest, if only the necessary data were in any way complete, which they very seldom are. Perhaps in one sentence we may say that that scheme, or system, or machine, will be the absolutely best in any particular case which will the longest survive and maintain its place in its particular environment. I cannot doubt that this development of Darwinian ideas in the world of the inorganic is a legitimate one. Of course the problem would be comparatively easy in each particular case if only the environment would stand still. It would even be comparatively easy if we knew how the environment was going to alter, but this we are unable to do. We only know that it certainly *will* change and will go on changing, and that therefore the things which we make now have not got to survive in the conditions in which we make them, but have got to survive through some new sets of conditions of which we know nothing. I do not think the difficulty is in any way met by the popular method of guessing at what will be wanted fifty years hence, which generally means simply guessing at something very big. It is of no use making our ships or our engines of a type which we choose to imagine will be that of fifty years hence. If we do they will be of no use to-day, and for that very reason they will not even be in existence, useful or other, at the end of the fifty years. Sufficiently sad illustrations of this will occur to everyone in very different directions. I hope I shall not be considered churlish in saying that I do not think that the men who have worked on this principle have really been far-seeing, or have really brought us much forward. They have been men often of genius, often of great personal fascination, always of immense imagination. But they have proceeded by methods essentially opposed to anything like the gradual evolution which must occur in technical as it does in natural matters, and in too many cases the results of their labours have not even been giants, but only monsters.

As to what causes one thing to survive rather than another we can only speak very generally. Mere survival may come about by the accident of a peculiarly tough constitution. A few engines built in the time of James Watt are still to be found at work in our own day, but can no more be taken as the fittest type than some solitary megatherium would be who, having outlived all his contemporaries, was able in after ages to look down upon his pigmy and short-lived successors. Mere length of life in such a case may be a mere accident, and is not itself a proof of fitness. We have it thrown at us every now and then that our engines nowadays do not last like the old ones, as if the mere existence of a very old machine were a proof of its virtues. It is certainly a proof of the excellence of its construction—or, as one may say, of its constitution—and perhaps also of the very small amount of work it has done in proportion to its life and its dimensions.

It is sometimes, I am afraid, rather humiliating to have to remember that, to a very great extent, the question of the fittest, so far as it affects us, is a financial one. In manufacturing processes efficiency and economy tend to survival because they lead to decreased cost of production. In structures or other large permanent works those types tend to perpetuate themselves which require the least material—that is, in which the material used is disposed to the best advantage—and in which the outlay on labour is also smallest, assuming, of course, equal fitness in other respects. There is, no doubt, at present a tendency to dispute this altogether, and to treat all reductions in cost of labour as disadvantageous, unless, indeed, the labour be very highly skilled, in which case its remuneration must necessarily be brought down for the sake of equality! I imagine this tendency will last exactly as long as the faithful can get some other people to pay the increased cost, and will thereafter determine itself somewhat suddenly. It can no more stand in the way of natural progress in engineering matters than could the somewhat similar outcry against the introduction of machinery into manufactures two generations ago. It would be as wise to paint a generation of cats green, in the hope of compelling natural selection to work along new lines.

I think we may fairly assume, therefore, that efficiency and economy are both legitimate criteria as to ultimate fitness, and will remain so. Moreover, they are both matters in which measurements can be made, and as to which judgment can be guided by such measurements. But there are other characteristics, not directly measurable, by which we can in some degree form an opinion as to the ultimate fitness of things or processes.

One set of considerations which has great critical importance is summed up in the word *simplicity*. This does not mean fewness of parts. Reuleaux showed long ago that with machines there was in every case a practical minimum number of parts, any reduction below which was accompanied by serious practical drawbacks. Nor is real simplicity incompatible with considerable apparent complexity. The purpose of machines is becoming continually more complex, and simplicity must not be looked at as absolute, but only in its relation to a particular purpose. There are many very complex-looking pieces of apparatus in existence which work actually so directly along each of their many branch lines as to be in reality simple. I believe it almost always happens that the first attempt to carry out by a machine a new purpose is a very complicated one. It is only by the closest possible examination of the problem, the getting at its very essence, that the machine can be simplified, and this is a late and not an early stage of design. If a mechanical problem is really only soluble by exceedingly complicated apparatus, it generally becomes a question whether the solution is worth having. There is no impossibility in making a machine that will do anything. But the very simplest possible form of apparatus which would wash our hands for us in a suitable manner is probably so very complicated that for many years to come at least that operation will be performed by manual labour.

Very closely allied to simplicity is what I may call directness. In nearly all mechanical processes certain transformations are unavoidable. In many mechanical processes, as I have recently had occasion to mention, a very large number of transformations is at present practically unavoidable. I myself cannot help thinking that probably one of the most distinct signs of fitness is a reduced number of transformations, the bringing of the final and the initial stages as close together as possible, and cutting out altogether the apparently worthless middle processes. But any generalisation of this kind must be very cautiously handled; these apparently useless processes are no doubt in certain cases as indispensable as is the much abused middle-man in matters economic.

In a critical view of any case where similar results are aimed at by hand work and by mechanical means, it is important to recognise that the similarity of result should very seldom become identity. In the first machine to do anything mechanically which has before been done by hand, the error is often made of trying to imitate the hand-work rigorously. The first sewing machines were, I believe, made to stitch in the same way as a seamstress. It was not until a form of stitch suitable for a machine, although unsuitable for hand, was devised that the sewing machine proved successful as a practical matter. In another but analogous line, too, you may remember that the first railway carriages were practically stage coaches put upon trucks, from which the present carriages have only very slowly been evolved.

The critic has also to remember that very often the attainment of some very unimportant point, or point of which the importance has been greatly exaggerated, is made the reason mechanically for very great complication. The question of proportion comes in here again, and it has to be considered in any particular case whether the academically perfect machine, which is also extremely complicated, is not inferior to the *almost* equally good machine which has been constructed in a practicable shape—it almost always is so.

I have endeavoured in my remarks to indicate what appears to me to be the attitude of the engineer towards a very large portion of the work which comes into his hands. In order to deal with the work it is necessary for him first of all to have a certain definite knowledge of 'things,' that is to say, both of the various subjects which form part of the curricula of all technical schools, and of the further matters which form as it were his professional alphabet. These last he learns not from books or lectures as a student, but by example and attempt, as does an artist. Of this part of his training I have said nothing; it has been perhaps sufficiently talked about of late years, and there is little to say which I could have made interesting to a general gathering like this. I cannot leave it altogether, however, without dealing with one matter. Exceptional men are all-round mathematicians or physicists, still more exceptional men are both; but for ordinary folk the study of one side of mathematics or of a single branch of physics is the work of a lifetime. The engineer is bound to know his own profession, by hypothesis, and it is in itself no small matter. Yet in addition he must know some mathematics, some physics, some chemistry, even also some geology, if he is to take any high rank in it. It is, therefore, surely in the very nature of things impossible that he should be a great mathematician or a great physicist, or should devote as much study to those most fascinating sciences as if they themselves were the work of his life. Therefore I beseech my friends of Section A to do what they can to modify their natural attitude of superiority—even of contempt—towards us, especially when we are students. The young engineer—I speak as a member of the great majority of the ordinary kind—would probably never have chosen his profession if he had had special aptitude for mathematical work. Having chosen it, he has to look at mathematics simply as a tool, a means to an end, not an end in itself. I cannot myself see that this point of view is one disrespectful to the parent of all the sciences, and I am confirmed by the knowledge that one or two of the greatest mathematicians in the country are of the same opinion and have the courage to act on it—with infinitely beneficial results to the young men they have to deal with. But I know that to mathematicians in general—the physicists are not so bad—the very name of engineering student is odious, indicating only a man who wilfully refuses to make mathematics his 'first subject,' and who therefore deserves neither consideration nor quarter, to whom it is privilege sufficient that he should be allowed to pick up such crumbs as he can digest from a table prepared for his betters. I humbly protest that we deserve better treatment. It is no doubt a great misfortune to us that we cannot afford to spend our training-time preparing for examinations, and that we have been compelled to choose for our future a career in which mathematics plays only a secondary part. It is our further misfortune that we have to solve twenty real live problems, each demanding a real live answer, for every single one which otherwise we would have worked out on paper. Perhaps it is also our misfortune—or it may be only our thickheadedness—to believe that in consequence of this we are quite able to judge for ourselves what units it is most convenient for us to work in, what nomenclature satisfies our requirements, and that we are as capable of getting our '*g*'s' in their right places as even some of our distinguished critics. But this is the end of the nineteenth century: philanthropy fills our breasts. May not our misfortunes call out some pity and not alone contempt? In spite of solemn warnings which I have lately received in the Press against the monstrous idea that a presidential address should contain any individual opinions, I venture to repeat here what I had lately an opportunity of saying before a Royal Commission, that in cases where a university or university college takes in hand the preparation of engineers (and I hope that such cases will grow in number) they should provide for them special training in mathematics, and probably also in physics, distinct from the general training in these subjects most suitable for Degrees. I say this with the full knowledge that I may be accused of wishing to degrade the purity of scientific work, and, at the same time, with the full knowledge that I have no such wish. On the contrary, this special training is the only means by which the rank and file of us will ever know any mathematics at all. And I can say from my own knowledge that, if only we can be made what I may call mathematically articulate beings, we shall be able to repay the kindness by placing before the man of pure science problem after problem of transcendent difficulty, of immense interest, and having no single drawback whatever except that its solution may really be 'useful;' and, after all, this need not be brought too prominently under his notice.

This digression has turned out a long one. I have only further to say that my main object in this address has been to indicate, as well as I could, the general attitude which the engineer must of necessity take up towards much of his work—the point of view from which he must look at it. I shall be extremely glad if anything which I have said should cause this attitude—this point of view—to be more clearly kept in mind in the period of training than probably has been hitherto the case.

The following Papers were read:—

1. *Some Reminiscences of Steam Locomotion on Common Roads.*[1]

By Sir F. J. Bramwell, Bart., *D.C.L.*, *F.R.S.*

2. *On Bore-hole Wells for Town Water-supply.*

By Henry Davey, *M.Inst.C.E.*

At the Cardiff Meeting of this Association the author proposed a new system of bore-hole wells for town water-supply. Since that time the system has been carried into effect at several places, and he described one of the most important examples of executed work, viz., that of the Netherley Pumping Station of the Widnes Waterworks. The subject was dealt with under two heads:—

1*st*. *The system of bore-holes.*

2*nd*. *The application of the pumping power.*

I. *The System of Bore-holes.*—In procuring water for town water-supply it is the usual and necessary practice to provide duplicate pumping engines, and where two engines are made to pump from the same well, the well must be very large that it may accommodate two sets of pumps.

Such wells are usually 12 to 14 feet in diameter.

To sink such a well in the ordinary way is a very long and costly undertaking, especially if soft strata are met with, where lining becomes necessary. On the completion of the well it may be necessary to drive adits to increase the water-supply. A simple bore-hole is made very cheaply and very expeditiously. Four 30-inch bore-holes can be put down in a very small fraction of the time required to sink a 12-foot well.

Instead of making a large well, the author puts down four bore-holes to accommodate the pumps for duplicate pumping engines—a pair of pumps to each engine. The bore-holes being completed, the pumps are lowered into them and coupled-up to the permanent engines. Immediately that is done the water found in the bore-holes can be pumped and supplied to the town. Should it be insufficient, then a small well would be sunk in the dry to the bottom of the bore-hole pumps. The water being kept down by the pumps, the bore-holes at the level of the pumps would be connected to the centre well, and adits driven to collect more water.

Should the bore-holes yield sufficient water, it would not be necessary to sink the well. It would be absurd to advocate any particular system of well-sinking as being universally applicable; this system, however, of making wells offers advantages under favourable conditions, but the advisability of its adoption in any particular case must be a matter of judgment with the engineer planning the work.

The bore-holes at Netherley, two in number, are sunk in Red Sandstone rock, and are placed 20 feet apart, each bored to a diameter of 30 inches for a depth of 200 feet, and to a reduced diameter of 18 inches for a further depth of 200 feet and 300 feet respectively, thus making the first hole 400 feet deep, and the second one 500 feet deep. On the completion of the boring the water stood 70 to 80 feet from the surface of the ground, when the quantity pumped by the old engine on the same site was 1¼ million gallons per day. The main pumps were then lowered into the bore-holes, each pump extending to the bottom of the large part of the hole, 200 feet from the ground-level. In that position the pumps were suspended from a cast-iron bed-plate supported on a concrete foundation formed round the top of the holes, a block of oak being inserted between the head of the pump and the bed-plate. In this suspended position the pumps work without the slightest unsteadiness.

The engines were made for the purpose of pumping 2½ million gallons per day, but it was found that, working up to their full capacity of 2¾ million gallons, the full yield of the bore-holes was not reached. On starting the new pumps it was found that when pumping 2¾ million gallons per day the water-level was lowered to 100 feet from the surface of the ground.

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[1] Published in the *Engineer*, August 17, 1894.

II. *The Application of the Pumping Power.*—The motive power consists of a 230 horse-power compound surface-condensing engine, employed to pump from the bore-holes into a masonry tank by the engine foundations, from which tank the water is forced by the same engine to a reservoir at an elevation of 260 feet. The engine is made to work the force-pump by means of a tail rod from the low-pressure cylinder, the bore-hole pumps being worked by means of rocking levers actuated by a connecting-rod from the crosshead of the engine. There is no flywheel or rotary motion, but a very simple expedient is resorted to to enable the engine to work expansively. This steam distribution is effected by giving a peculiar bell crank form to the levers which convey motion to the well pumps. The effect of this mode of coupling the pump piston or plunger to the engine piston is to make the pump-resistance diagram so nearly approach the shape of the combined engine diagram that the weight of the moving parts of the engine is of itself, by its inertia, sufficient to equate the two diagrams.

Steam Distribution.—The engine is of the receiver type, having separate expansion valves on both high- and low-pressure cylinders, adjustable by hand whilst the engine is in motion.

A careful trial of the engine has been made, and as it is provided with a surface-condenser, it was quite easy to ascertain the exact quantity of steam used by the engine by measuring the air-pump discharge, and adding that discharged from the steam-jackets.

The efficiencies are as follow:—

1. *Engine efficiency*: the proportion which the area of the actual indicator-diagrams bears to the area of the theoretical diagram for the steam admitted to the engine = ·644.

2. *Mechanical efficiency*, or the portion of the indicated power utilised by the pumps = 87 per cent.

3. *Thermal efficiency*, or the portion of the energy due to the fall in temperature of the steam which has been utilised by the engine = ·433.

Units of work per unit of heat = 110 8.

The steam-cylinders are both steam-jacketed completely—bodies and ends—with steam at boiler pressure.

The following summary gives the general particulars and cost of the installation:—

Steam pressure	70 lb. per sq. inch.
Diameters of cylinders	32 in. and 60 in.
Length of stroke	6 ft. 3 in.
Diameter of force-pump	18½ in.
Height of lift	260 ft.
Length of stroke	6 ft. 3 in.
Diameter of bore-hole pumps	18½ in.
Height of lift	100 ft.
Length of stroke	6 ft. 6 in.
Number of strokes per minute	12½
Depth of bore-holes	400 and 500 ft.
Diameter of bore-holes	30 in. for 200 ft., and then 18 in.
Tube surface of condenser	420 sq. ft.
" " feed heater	140 sq. ft.
Water pumped in 24 hours	2½ million gallons.
Duty of engine on an evaporation of 10 lb. water per 1 lb. coal	124 millions.
Lbs. of steam per I.H.P. per hour	15·6
" " P.H.P. "	18·0
Indicated horse-power	230
Pump horse-power	200
Mechanical efficiency	87 per cent.
Cost of engine and pumps	6,000*l.* = 30*l.* per P.H.P.
Total cost of engine, pumps, bore-holes, and buildings	9,700*l.* = 48½*l.* per P.H.P.

FRIDAY, AUGUST 10.

The following Papers were read :—

1. At a joint meeting with Section A :—

(*a*) *On Planimeters. By* Professor O. HENRICI, *F.R.S.*—See Reports, p. 496.

(*b*) *Note on the Behaviour of a Rotating Cylinder in a Steady Current. By* ARNULPH MALLOCK.

(*c*) *On the Resistance experienced by Solids moving through Fluids. By* Lord KELVIN, *P.R.S.*

(*d*) *A Discussion on Flight. Opened by* Mr. HIRAM S. MAXIM.

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2. *On the Strength and Plastic Extensibility of Iron and Steel.*
By Professor T. CLAXTON FIDLER, *M.Inst.C.E.*

1. For several reasons the stress-strain diagram, as autographically drawn in connection with the testing of a ductile material, does not suffice to indicate any definite relation between tensile stress and plastic strain. The stretching effect of the load is commonly measured before it is fully developed; the ordinates of the diagram represent stress per unit of original area, but cannot represent the actual unit stress, which varies in different parts of the bar; and, lastly, the elongation measured by the diagram is the elongation of the whole bar, and is the sum of the component elements of elongation, which vary still more widely in different parts of the bar.

2. Analysing the total elongation, and plotting as co-ordinates the actual intensity of stress in any short segment or element of the bar, and the actual elongation in the same element under a long-continued load, the curve takes a very different form, and is probably already familiar to those who have taken a special interest in the subject.

3. So far as the author's direct experiments have gone, the curve so traced appears to be almost identical for all parts of a fairly homogeneous bar, indicating that the plastic extensibility, or the actual extension under any given stress, is nearly the same in all segments of the bar's length, even when the ultimate elongation varies, as it often does, between 12 per cent. and 120 per cent. in the different segments.

4. Volumetric measurements of the successive segments indicate that there is no sensible telescopic shear, or internal flow of material from one segment to another (except at one point, which need not be here noticed), and justify the general application of the assumption of unchanging volume.

5. Probably, therefore, the curve may be taken to represent the variable length x assumed by each component internal element under the long-continued stress y, as well as the variable length of any cylindrical segment under the same stress, the original length of the element or segment being denoted by L.

6. It may at first sight be supposed that a bar of uniform plastic extensibility ought to draw out uniformly over its whole length; but when the curve is considered along with the mechanical conditions affecting the question, they seem sufficient to explain the observed behaviour of the bar. Beyond a certain critical point a uniform extension is almost impossible, just as the uniform compression of a long and slender strut is impossible. The formation of a short narrow neck in some part of the tie-bar is inevitable—like the buckling of the strut.

7. To illustrate these points and some others the curve, as approximately determined for a bar of mild steel, was shown in the diagrams exhibited, and its regularity suggests the existence of a definite law of extension. As the length x

increases, the resistance of the material increases continuously up to the point of fracture. Nevertheless, it is shown that, as x increases, the relations between the stretching force and the resistance pass from a condition of stable, through indifferent, to unstable equilibrium. The law of plastic extension, $y = \phi(x)$, as defined by the curve, fixes mathematically the occurrence of the 'plastic limit;' and it fixes also the 'breaking weight per square inch of original area,' which can have only one value, and is easily found by graphic construction. The breaking weight of the tie-bar as thus defined depends upon the plastic extensibility, in much the same way that the breaking weight of a strut depends upon the elastic modulus.

8. Examining next the possibilities of deformation in a bar of uniform or nearly uniform extensibility, it may be seen that, as the plastic limit is approached, the slightest irregularity in section or in extensibility tends to precipitate the formation of a contracted region, and ensures that beyond that limit the further extension of the bar and the further contraction of area will be confined to the same region. For stresses below the plastic limit the probabilities of deformation may be examined by considering the relative time-rates of extension at two elements which may have been unequally stretched, and at first the tendency is theoretically in favour of preserving the cylindrical form of the bar. But beyond the plastic limit these conditions are reversed, and the tendencies are all in favour of precipitating the most rapid contraction of area at the point where any contraction already exists, and thus to pinch in still further the region where any contraction of form has begun to show itself.

The observed phenomena agree very well with these deductions, and may be rationally attributed to the operation of the mechanical conditions named.

9. Going back to the yield-point, the sudden elongation which here takes place appears to be something different from plastic extension. Examined analytically, the process is found to take place at somewhat different stresses in the different segments, while in any one short element or segment it seems to be instantaneous. If the yield is arrested midway and the bar examined, it is sometimes found that the elongation has been quite completed in some segments, and not even commenced in others. This irregularity is greater than anything met with in connection with plastic extension, and may account for the variations of form observed in autographic diagrams at this point. When the process has taken place throughout, it constitutes an elongation which is almost uniform throughout the bar, and after the yield the segments fall into line and exhibit a nearly identical curve. As regards the slight curvature below the yield-point, it may be doubtful whether this indicates the commencement of yield in some short elements, or the commencement of a plastic extension in the course of which the yield occurs as a separate incident.

10. The author recognises the insufficient nature of his experimental data, and the need for further study and more refined measurements of the true curve of plastic extension; but judging from the results obtained, some formulæ are suggested as representing the probable law of plastic extension for such a ductile material.

11. In the paper some further experiments are described which were made with the object of measuring the extensions on a larger scale, and of testing some of the propositions before referred to.

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3. *On Tunnel Construction by means of Shield and Compressed Air, with special Reference to the Tunnel under the Thames at Blackwall.* By MAURICE FITZMAURICE.

Since 1892, when Mr. George F. Deacon read a paper before the British Association on the construction by means of shield and compressed air of the Vyrnwy Aqueduct Tunnel under the Mersey, other and larger tunnels have been constructed and are now in course of construction in this country by the same methods.

Three tunnels have been thus completed under the Clyde just below Glasgow, and tunnels at several points in Glasgow are being made in connection with the Glasgow District Subway. A tunnel is also being constructed in Edinburgh by the same means. In all these tunnels compressed air has been used in conjunction with shields almost continuously, as the amount of water met with has been large, and it has been necessary in most cases to avoid all subsidence of the ground above as much as possible.

The tunnel under the Thames at Blackwall which is being built for the London County Council under the direction of their chief engineer, Mr. A. R. Binnie, has now been under construction for more than two years, and although the greatest difficulties have probably yet to come, still an account of the present state of the work and the difficulties met with up to date will, it is hoped, not be without interest.

Before dealing with the Blackwall Tunnel the author made a few remarks on previous tunnels constructed by one or both of the methods under consideration.

The tunnel under the Thames between Wapping and Rotherhithe, constructed by Brunel between the years 1825 and 1842, was the first tunnel constructed by means of a shield, and its history is so well known that it will not be necessary to refer further to it. It may be noticed, however, that in a patent of Brunel's taken out in 1818 he had at that time conceived the idea of a tunnel made of cast iron with an inside brick lining, and constructed by means of a shield which had a tail lapping over the completed portion of the tunnel and shoved forward by means of hydraulic rams.

Cochrane took out a patent for using compressed air in the construction of shafts and tunnels in 1833, but it was not used for the former until 1839, and was not used in any tunnel before 1872 or 1873.

The use of compressed air in conjunction with a shield, and the construction of the tunnel itself with cast-iron rings, although the latter may not be so important in some cases, may be considered the key to tunnelling in loose or soft ground filled with water.

The question of settlement, especially in towns, is a very important one. When pumping has to be done the water is naturally drawn down in the adjacent strata, and in addition quantities of sand often come with the water, and settlement occurs from the first or from both of these causes. When compressed air is used no pumping, of course, is necessary, and therefore there can be no settlement under that head. Probably the most fruitful cause of settlement in ordinary tunnels is caused by the fact that more ground is taken out than the tunnel actually fills, and although the utmost care is taken in supporting the ground and packing all cavities, a certain amount of settlement invariably occurs. With a shield the excavation is reduced to almost the net section of the tunnel, and therefore no settlement can take place to any appreciable extent. As regards safety in working, it is evident that when only the face of the excavation is open, and that, perhaps, only in small areas, and the water is kept back by compressed air, the maximum of safety is assured. The great advantages of constructing the tunnel of cast-iron segments are, that it is much quicker to build than anything else, and that it has its full strength as soon as it is built; and this latter is a very important matter in soft ground, which exerts a heavy pressure on the tunnel.

The Tower Subway, 7 ft. 1¾ in. in external diameter, constructed by Mr. Peter Barlow in 1869, is interesting as being the first tunnel in which a shield shoved forward as one structure was used, and for the construction of which cast iron was adopted. It was driven through London clay, no water had to be dealt with, and no difficulties were encountered. In 1870 an experimental length of tunnel 8 ft. in external diameter was driven under Broadway, New York City, by means of a shield, to demonstrate the practicability of constructing tunnels by this method without injuring buildings by settlement. Between 1870 and 1874 tunnels of 6 ft. diameter were driven by the same means under the streets of Cincinnati for drainage purposes, and for 1½ mile under Lake Erie for the supply of water to Cleveland, Ohio.

The first large tunnel completed by means of shields and compressed air was the St. Clair Tunnel, finished in 1890. It was constructed with cast-iron segments of an outside diameter of 21 ft., and compressed air up to a pressure of 32 lb. was used. This tunnel was principally through soft clay, and the maximum progress in one month at one face was 382 ft.

About the same time Mr. J. H. Greathead completed the City and South London Railway in London. It consists of two tunnels, made of cast-iron segments, 10 ft. 6 in. in diameter each, and 3 miles long. Compressed air was only necessary for short distances at three points, as it was principally driven through London clay.

Previous to the construction of the St. Clair Tunnel compressed air had been used in the Hudson Tunnel, which still remains unfinished owing to financial difficulties. The greater portion of its length is constructed of cast-iron rings of 19 ft. 8 in. diameter.

In 1891 Messrs. Pearson and Son's tender for the construction of the Blackwall Tunnel, amounting to 871,000*l.*, was accepted by the Council, and the work was commenced in 1892. Mr. D. Hay and the author were appointed as resident engineers under Mr. A. R. Binnie, and Mr. E. W. Moir took charge of the works for the contractors.

The Blackwall Tunnel is much larger than any tunnel yet constructed by the methods adopted. The outside diameter of the St. Clair Tunnel, which is the largest one at present, is 21 ft., while that at Blackwall is 27 ft. in external diameter.

The following are some of the leading dimensions:—

	Ft.	in.
Length from entrance to entrance	6,200	0
This total distance is divided as follows:—		
Open approaches, flanked by retaining walls	1,735	0
Cut-and-cover portion, built of brick and concrete	1,382	0
Cast-iron-lined portion	3,083	0
The width of roadway is	16	0
And the width of each footpath	3	1½

The tunnel is level under the river, and the gradient on the north side is 1 in 34, and on the south side 1 in 36. There are four vertical shafts, two on each side of the river, and varying in depth from 75 ft. to 100 ft. below ground level. Each shaft is a wrought-iron caisson of 58 ft. external diameter at the bottom, and 48 ft. internal diameter throughout, and lined with brickwork. Each caisson consists of two wrought-iron skins, 5 ft. apart, braced together, and terminating in a cutting-edge. Two circular holes, which are temporarily plugged while sinking, are left in each caisson to give way for the tunnel through the shaft, and provision is made for an airtight floor above the level of the tunnel when necessary. The space between the two skins is filled with concrete. Two caissons have been sunk, and the two others are in course of being sunk.

The tunnel is constructed of cast-iron rings 2 ft. 6 in. long, and each ring consists of fourteen segments and a key-piece. The thickness of metal is 2 in. and each segment has flanges 12 in. deep, and both longitudinal and circumferential joints are planed.

The shield used for the construction of the tunnel is 19 ft. 6 in. long, and is 27 ft. 8 in. in external diameter. The outer shell consists of four ⅝-in. steel plates. The shield is divided into a front and back portion by two vertical diaphragms at right angles to its axis. It is thus possible, when necessary, to have a higher air pressure in the working face of the shield than in the completed portion of the tunnel. The space between these two diaphragms forms an air-lock, both diaphragms, of course, being provided with doors, by which access to the working face is obtained. At the back of this air-lock the shield consists only of the outer shell, which always laps over and outside at least one completed ring of the tunnel, and inside of which all the rings are built. The space of 4 in. left outside the rings when the shield is shoved forward is filled with grout, forced in by air pressure through screwed holes made in each segment for the purpose. Everything is, therefore, quite solid at the back of the cast-iron lining. At the air-lock and in front of it there is an inner shell, connected stiffly to the outer shell by circular girders and in other ways, and both joining together at the cutting-edge. The working face is divided into four horizontal floors and twelve working chambers by vertical and horizontal diaphragms in the line of the axis of the shield. A hanging iron screen in each compartment about 6 ft. back from the cutting-edge forms a safety chamber at its back, where men could stand with their heads above water in case of a rush of water in the face due to air blowing out suddenly, or from other causes. Provision is made for using iron poling boards at the face, shoved forward by jacks, when in ballast, if necessary. The shield, which weighs about 250 tons, is shoved forward by twenty-eight hydraulic jacks fixed at the back and butting against the cast-iron lining, and able to exert a total pressure of over 3,000 tons.

At the present time the portion of the tunnel between shafts No. 4 and No. 3 has been constructed. The shield was started from No. 4 shaft in June 1893, the first permanent ring being erected on June 9. When first starting the face was nearly all clay, there being a little ballast at top and a little fine sand at the bottom. It was therefore decided to go on without compressed air for some time, and in three months seventy-seven rings, being equivalent to a length of 192 lineal feet, were erected. This length was done with practically no timbering, except in the top ballast for a short length, in which a good deal of water was met. A little previous to this time the cutting-edge at the bottom of the shield got bent by shoving the shield against a layer of rock which was met in the clay, and it was found now to have got much worse. It was therefore considered better to drive a timbered bottom heading in front of the shield, and put in a concrete foundation on which the shield could be shoved forward to the next shaft. This was done for the bottom 6 ft. of the shield, all the excavation above this level being done without timbering. In this way by the middle of December, six months after starting, 191 rings, equivalent to 477 lineal feet, had been erected.

As the tunnel was going down a gradient of 1 in 36, and the top of the sand remained nearly level, the latter was now up to the middle of the shield, and was carrying a great deal of water. On December 16 there was a rush of water and sand, which filled the heading with sand, and the water rose 15 ft. in the tunnel at the shield.

As the shield was now close to No. 3 shaft, which was not yet sunk to its full depth, it was considered safer not to continue the tunnel until the shaft was sunk, and in the meantime to make preparations for using compressed air when work was again started. A concrete bulkhead was therefore built across the tunnel, with air-locks in it, a little back from the shield, and when the shaft had been sunk to its full depth, work was recommenced in the tunnel on March 23, under air pressure of about 15 lb. to the square inch.

No further trouble from water was then experienced, and by going on in the same way as above described with a bottom heading, the shield was got into No. 3 shaft in May. It is now being strengthened and repaired there, preparatory to starting under the river from No. 3 to No. 2 shaft.

In the deepest portion of the river, where the top of the tunnel comes within 7 ft. of the river bed, which is all gravel at this point, it is proposed to lay a bed of clay 10 ft. thick in the bottom of the river, to prevent the compressed air blowing out; and with this precaution it is hoped that no difficulty will be met with in this portion of the work which cannot be overcome by the experience already gained in the portion between shafts No. 3 and No. 4.

SATURDAY, AUGUST 11.

The following Papers were read:—

1. *On Methods that have been adopted for measuring Pressures in the Bores of Guns. By* Sir A. NOBLE, *K.C.B.*, *F.R.S.*—See Reports, p. 523.

2. *On the most Economical Temperature for Steam-engine Cylinders; or, Hot* v. *Cold Walls. By* BRYAN DONKIN, *M.Inst.C.E.*

The author calls attention to the important question of the most suitable temperature of cylinder walls to obtain the maximum economy by reducing condensation in steam cylinders to a minimum. To diminish condensation his experiments prove that it is essential to reduce the difference of temperature between the incoming steam and the cylinder walls. In most cases the cylinder walls are much colder than the steam, and often one-half the weight of steam is condensed during admission. Many experiments show that the nearer the temperature of the cylinder wall is to that of the entering steam the greater is the economy. With walls 40° to 60° Fahr. colder than the steam, as is often the case, the consumption is greatly increased, owing to the large amount of condensation. On the other hand, the cylinder metal can be made too hot and heat wasted at exhaust. This has also been experimentally proved by the author. The best results in steam economy have been obtained when the temperature of the internal surfaces is a little higher than that of the entering steam.

Cylinder walls can be heated in various ways. The most usual is to raise their temperature and that of the covers, by means of boiler steam introduced into the jacket spaces. Another method, and one used a good deal on the Continent, is to work with superheated steam. This steam has been employed in some cases with advantage in the jackets as well as in the cylinders. Smoke jackets have generally proved a failure. When the jacket is connected to a condenser having a good vacuum, economy of steam is also obtained, but not so much as with steam in the jackets. To secure the maximum economy also, it is important not only to diminish the volume of the clearance spaces, but especially to reduce as much as possible the area of the clearance boundary surfaces. In this way the weight of iron heated and cooled per stroke so many degrees can be materially diminished. The character of the internal surfaces, whether rough from the sand or turned, and their position, horizontal or vertical, have also some influence on the transmission of heat and condensation of steam, as verified by recent trials.

Experiments have also shown that the cylinder wall in any working steam engine is divided thermally into two parts; the outer portion remains at a constant temperature, and the inner or periodic portion is heated with each steam, and cooled with each exhaust stroke. The relative proportion of these two parts, or the depth to which the heat penetrates into the metal, depends largely upon the speed of the engine, and on the temperature of the cylinder relatively to that of the entering steam. In a non-jacketed engine, with one-inch cylinder walls, working at thirty-five revolutions per minute, the depth to which the heat penetrates and fluctuates per stroke is at least about eight to nine millimetres from the internal surface. The depth of heat-penetration for the same speed is much less with hot than with cold walls; a less weight of metal is heated per stroke; and condensation is found to be much reduced.

The author gives some of the results of eighty experiments on a small vertical engine, with cylinder 6 in. diameter and 8 in. stroke, made expressly for experimental research. The details are to be published in 'Proceedings of the Institution of Mechanical Engineers.' The engine was worked with very different temperatures of walls, and many tests were made, condensing and non-condensing, jacketed and non-jacketed, single and double acting, at different expansions, and with both saturated and superheated steam in the cylinder and jackets. Care was taken in these experiments only to vary one set of conditions at a time. Results of two experiments are added, one with hot and the other with cold walls, or one with steam and the other with air in the jackets. Both tests were made condensing, double-acting, with 50 lb. steam pressure, $\frac{3}{16}$ cut-off, and at a speed of 220 revolutions per minute. The walls were some 30° Fahr. hotter with than without steam in the jackets; the steam consumption per I.H.P. per hour was reduced from 41¼ lb. to 28⅓ lb., or about 31 per cent.; the thermal efficiency was increased from 5·7 to 8·1 per cent., or 40 per cent., and the rate of initial condensation was reduced from 460 lb. to 217 lb. per square foot per hour, or by more than one-half. The percentage of steam present in the mixture during expansion was also increased by about 50 per cent.

Throughout these experiments an increase of economy with the hotter walls was always verified; the thermal efficiency was higher, the initial condensation less, and the percentage of steam present during expansion always increased.

The tests on this engine point to the practical conclusion that the range of steam temperature in the cylinder per stroke has much less effect on the steam consumption than the temperature of the walls.

The paper may be shortly summarised thus:—The most uneconomical results were always obtained with the cylinder walls colder than the entering steam. Under these conditions considerable initial condensation was produced, drops of all sizes up to 3 mm. diameter being formed and running down the cold surfaces. The heat also penetrated into the colder walls to a considerable depth, a certain quantity being given up by the steam at every stroke, to raise the temperature of the internal surfaces after exposure to the condenser temperature. Both at cut-off and release there was a great deal of water in the cylinder compared with the weight of steam present. On the other hand, the most economical results were always obtained when the cylinder walls were at about the same temperature as that of the entering steam. Under these conditions the rate of initial condensation was very much lower, and the drops of water formed much smaller in size. The heat penetration into the walls was also much less, a smaller amount of steam sufficing to heat the internal surfaces after being cooled by the condenser. The percentage of steam present in the mixture, at cut-off and release, was also very much increased.

If engineers and others using steam engines wish to work economically and with smaller boilers, they must arrange to keep their cylinders and covers as hot as the steam entering the cylinder; otherwise the cylinder becomes unintentionally an efficient condenser, with a large area of cooling surface.

Properly applied steam jackets are economical, because they raise the temperature of the walls touched by the steam. Those who cannot steam-jacket the whole cylinder should at least jacket the two covers, which are the most important surfaces.

Well-arranged jackets with proper-sized pipes for entering steam and exit water, without places for air to collect, are an excellent investment, and pay a good interest on the small additional cost.

MONDAY, AUGUST 13.

The following Papers were read:—

1. *On Signalling through Space. By* W. H. Preece, *C.B., F.R.S.*

2. *On Some Advantages of Alternate Currents.*
By Professor Silvanus P. Thompson, *F.R.S.*

3. *Continuous-current Distribution of Electricity at High Voltage at Oxford.*
By Thomas Parker, *F.R.S.E., M.Inst.C.E., M.Inst.M.E., M.Inst.E.E.*

The Central Station at Oxford was started in the middle of the year 1892, and is equipped with high-tension continuous-current dynamos driven by means of belts from triple-expansion vertical engines; it is placed 1,500 yards away from the area of lighting. The current is distributed by means of a network, which is fed by motor generators transforming from 1,000 to 105 volts. These motor generators are started, stopped, and regulated from a central switch station placed in the area. The main feature of the system is the complete control of the motor generators from the switch station; and the number connected on to the network being varied to suit the load, it is possible to always work the transformers at a high efficiency. A small battery situated at the switch station is used to supply the small day and night loads, thus enabling the Central Station to be entirely shut down for a great portion of the twenty-four hours.

The figures for 1893 show that the total efficiency of the system was 61·62 per cent., and the efficiency of the motor generators was 74·44 per cent., including losses in mains and resistances. This is not so high as it will be in the future, when the lamps are more evenly distributed over the area. The battery efficiency was 50·64 per cent. The actual coal used throughout the year works out to 6·83 lb., or ·718 penny per unit sold, which is a very good result, as only slightly over 100,000 Board of Trade units were metered. The oil, waste, water, and general engine-room stores work out to ·0657 penny per unit metered. The total number of lamps installed at the beginning of the year was 4,041, which increased to 7,012 by the end of the year. As the great proportion of supply is taken up by colleges, the term-time is the only part of the year when anything like a load can be obtained, and the load factor is only 6·31 per cent.

The revenue during the year under notice was 10*s.* 11*d.* per 35-watt lamp installed.

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4. *On a Special Chronograph.*

By HENRY LEA, *M.Inst.C.E.*, *and* ROBERT BRAGGE.

In his capacity as electric inspector for the city of Birmingham the duty of one of the writers is to test the accuracy of the electric meters used in that city. The test involves an accurate measurement on the one hand of the current of electricity passing through the meter, and on the other hand of the period of time during which the current of electricity effects a certain number of revolutions of the meter armature.

For the electrical measurements he selected a Crompton potentiometer, but as his chronograph was not accurate enough he drew up a specification upon which the English Watch Company built the chronograph exhibited to the meeting. The ideal chronograph is one with a perfectly divided dial, an absolute prompt start, a definite stop at zero, and a continuous or running motion of the hand.

The test-room chronograph under notice is not intended for use as a watch; it is purely and simply a micrometer applied to time, and therefore it has only two pointers—one from the centre, giving seconds and their fractions, the other placed halfway between the centre and circumference, showing minutes up to sixty. The dial of aluminium, being engine divided, is mechanically perfect; and being of large size, 2¼ inches of sight, the divisions of ten to the second are clearly defined.

The prompt, absolute start is obtained by dispensing with all intermediate gearing and relying on the main train of wheels impelled by the ordinary mainspring. The starting lever not only releases the balance-wheel, but at the same time by the momentary contact of a light spring blade impels the wheel in the required direction.

The absolute stop at the end of an observation is obtained by the frictional contact of the aforesaid spring blade with the edge of the balance-wheel.

The absolute stop at zero is obtained by fixing upon the axis of the seconds wheel a collet carrying a blade. Upon the top of the movement there is a lever, which, during the period of an observation, is held back; but when the observation is concluded it is set free by a push of the button, and falls to a point where it crosses the path of the blade already referred to, and stopping the wheels brings about the absolute stop we require.

The last thing requisite is for the seconds hand to have a continuous run. Everything tried up to the present has had a tendency to accelerate its rate, and is therefore inadmissible. The lever escapement has been adhered to, and by using hard stone jewellings, and by observing great accuracy in the angles of the pallets, the makers are enabled to double the ordinary number of beats—36,000 instead of 18,000—and although in every beat there are three processes, the whole follow so smoothly that the progression of the hand is practically continuous.

5. *On a Direct Reading Form of Platinum Thermometer.*
By G. M. Clark, *B.A.*

The author described the pyrometer of Callendar and Griffiths. In this instrument the leads to the platinum coil are so arranged that only a single observation is necessary to determine its resistance. Further, by constructing the galvanometer so that its deflections are independent of the E.M.F. of the battery, the same increase of resistance of the coil will always give the same deflection on the scale. A wide range of temperature as well as an open scale is secured by the galvanometer being brought back to zero every hundred degrees. It is also pointed out that the 'fixed points' of these thermometers are not liable to variation.

As reliable experiments with the air thermometer above 700° C. have not yet been carried out, the author suggested the adoption of a platinum thermometer with fixed coefficients as a standard.

TUESDAY, AUGUST 14.

The following Report and Papers were read:—

1. *The Report of the Committee on Dryness of Steam.*—See Reports, p. 392.

2. *On the Temperature Entropy Diagrams.*
By H. F. W. Burstall, *M.A.*, *A.M.Inst.C.E.*

The treatment adopted in this paper has been to consider the temperature entropy diagrams, from the engineer's point of view, and as far as possible graphical methods are alone employed.

The reason of the great value of the diagrams lies in the fact that an area represents the heat required to effect the change denoted by the contour of the area; and when the actual expansion of the steam is plotted on the heat diagram it is easy to see by inspection where the losses of heat have occurred.

The ordinates of the curves are the absolute temperature and the entropy or heat weight.

The curves denoting the heat required to form a given mixture of steam and water can be drawn once for all; after that very simple arithmetic is all that is required to trace the expansion curve for any engine on the heat diagram.

The changes in the pressure and dryness of steam confined in a constant volume are shown by means of a model in space, in which the vertical distances represent the volume of steam, and the horizontal plane a temperature entropy diagram. On cutting the surface formed by a plane parallel to the horizontal plane we have a curve which gives the constant volume curves, and the construction follows at once from the model.

The paper was illustrated by diagrams from several types of steam engines, both compound and triple expansion, and the diagram for a gas engine was also shown.

3. *On the Hunting of Governed Engines.*[1]
By James Swinburne, *M.Inst.C.E.*

Governors are generally considered as complete mechanisms without reference to the engines governed. Hunting, however, depends, not only on the governor, but also on the inertia of the fly-wheel and the load on the engine. A Watt governor acting directly on the throttle or expansion valve does not hunt if designed for stability, but does not give the same speed at heavy as at light loads. If made isochronous it has either a dash-pot or a relay. In either case the action of the governor is not instantaneous, and a time-lag is introduced. This causes hunting, especially if the load is light and the fly-wheel heavy or fast-running. If the isochronous governor works a slow-acting relay the hunting may be so serious that the steam supply alternates between complete cut-off and full supply. The remedy is to use either an isochronous governor with no relay, so that the engine gets either full steam or none, or to use a stable governor acting direct with a supplementary relay gear to secure the same speed at full and light loads. The first method is not employed in large slow-running engines, as the fly-wheel would have to be enormous. The second is utilised in the Knowles supplementary governor, but a second governor is unnecessary, as one can fill both functions.

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[1] Published in full in *Engineering*, August 17, 1894.

4. *On Engineering Laboratory Instruments and their Calibration. By* DAVID S. CAPPER, *M.A., Professor of Mechanical Engineering, King's College, London.*

The reliance to be placed upon observations made with measuring instruments evidently depends primarily upon the accuracy with which those instruments record. Neglect of this fundamental truth often leads to inaccurate and erroneous deductions from experiments which are themselves of the highest scientific value; not infrequently the whole value of observations may be destroyed by insufficient care in the calibration of the instruments used. The subject is therefore one of some importance. The author describes the chief sources of error in some of the most common engineering investigations, and their probable value, and points out some of the possible methods of correction where such exist. For example, in engine trials there are many possible sources of error. Most of these may be reduced in percentage value by continuing the trial for a sufficient period. But this is not the case with errors which may occur in the indicators, gauges, or spring balances used in the determination of power. In these, unless properly calibrated before trial, very serious errors may be introduced, amounting in some cases to 5 and 6 per cent. of the total power indicated. It is therefore absurd, even if proper precautions have been taken, to rely upon horse-power measurements to two places of decimals.

Similarly with regard to tension and compression experiments with standard 10-inch bars. Here calibration of the testing machine is extremely difficult, and can in general only be carried out over a small portion of the range of the experiments. Deductions have therefore to be made from the less to the greater, with the result that small errors in the calibration will tend to be magnified. Vertical testing machines have fewer sources of error, and can be calibrated with more certainty, than horizontal machines. Extensometers are, however, much more easily applied to a horizontal bar than a vertical, and variable jockey weights, which are requisite if the same accuracy is to be maintained at low loads as at high, are also more readily adapted to horizontal machines.

Extensometers can be made and calibrated well up to the accuracy of the testing machine. With standard bars and a measuring instrument true to the ten-thousandth of an inch, the modulus can be relied upon to the second significant figure. It is doubtful if more can be obtained without very special construction and calibration of the testing machine.

The difficulty in bending experiments, again, lies in the accurate application of load. Unless the beams are very short or of unmanageable cross-sections, the load measurement must be very delicate if readings approaching the accuracy of those in tension are to be obtained. It is possible that some of the discrepancies in published beam experiments may be due to this cause.

The paper deals shortly with other cases where calibration is specially needed, to which the limits of this abstract do not permit a more extensive allusion.

5. *On Lighthouse Apparatus and Lighthouse Administration in* 1894. *By* J. Kenward, *F.S.A.*, *Lighthouse Engineer.*

The writer referred to the principles that govern the establishment of modern lights, and described the chief forms of apparatus now best available for the optical engineer, *e.g.*, the single flashing or the group-flashing holophotal revolving; the fixed and occulting; the lenticular revolving, having refracting centres alone, extended to high vertical angles; and the quick-flashing lights of recent French types called *feux-éclairs*.

He compared the dimensions or 'orders' of various apparatus, and the radiants of gas, oil, and electricity, and discussed the question of *fog* in relation to these.

He called attention to the need of good ship-lights on the dioptric system, having equality of power in the beam.

He suggested certain reforms in lighthouse administration and in lighthouse statistics.

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6. *On Spring Spokes for Bicycles. By* Professor J. D. Everett, *F.R.S.*

The author described a construction of spring-spoked wheels for bicycles in which both lateral and rotational yielding are so moderate in amount as to occasion no inconvenience. Each spoke consists essentially of a small coil spring, weighing half an ounce, attached to a light spoke wire, the connections of the ends of the spoke to hub and rim, as well as the connection between spring and wire, being of the hook-and-eye kind. The attachment to the rim is made, not at the centre of the rim, but at its edges, semicircular notches being cut, into which the spokes are hooked, and the spokes attached to either edge of the rim are attached to the opposite flange of the hub, so as to cross the plane of the wheel. The spokes of the driving-wheel are not exactly radial, but slope a little backwards and forwards alternately—an arrangement which materially diminishes rotational yielding, while the crossing above described diminishes lateral yielding.

It has generally been maintained that, while up-and-down elasticity is useful for relieving jolts, lateral and rotational yielding are evils to be avoided. The author differs from this view, and maintains that both lateral and rotational yielding, of the elastic kind, when kept within proper limits of magnitude, are beneficial both as regards comfort and speed.

When one of the wheels of a bicycle encounters an obstacle (such as rough roads abound with), the collision produces an impulsive reaction on the wheel, as if the obstacle struck the wheel. Sometimes the direction of the blow lies in the plane of the wheel, but in many cases the wheel is not only checked and lifted, but at the same time driven to one side. In order to cushion the lateral component of the blow there must be lateral yielding. Accordingly, in running over patches of stones, which jerk the ground-point of a wheel from side to side, the usual jarring of the hands and disturbance of the steering are noticeably absent in bicycles with spring spokes.

As regards a blow delivered in the plane of the wheel, the impulse may be resolved into a radial and a tangential component. The radial component is cushioned by the shortening of the spokes in the neighbourhood of the point of impact, and the lengthening of the diametrically opposite spokes.

The tangential component is equivalent to an equal and parallel impulse on the rim in a line passing through the centre, combined with a torque. The torque, from the symmetry of its action round the axle of the wheel, produces no jar; but the impulse in a line through the centre tends to drive the rim backwards and slightly downwards, with respect to the axle. It is cushioned by the elastic shortening and lengthening of spokes which are nearly horizontal.

The elastic yielding of a pneumatic tyre is mainly in the radial direction, and is practically nil in the tangential direction. Its lateral yielding is very much less than that afforded by spring spokes.

Next, as regards rotational yielding of the driving-wheel, the propelling force applied by the rider to the pedals is given out at the ground-point of the wheel in the shape of back-pressure of the wheel against the ground. The more rigid and unyielding the connection between these two parts of the mechanism is, the greater will be the tendency to jarring of the feet by inequalities of the ground. Even on smooth ground there is a jerk at the beginning of each stroke, in the case of an unyielding wheel, which tends to fatigue the knee. The difference between the energy given to the springs and the energy which they return is quite trifling in comparison with the saving of energy which results from the easing-off of concussions. Moreover, the energy stored in the springs is useful in carrying the wheel past the dead-points, a small pressure unconsciously exerted on the pedals being sufficient to retain the energy till it is wanted.

An indirect benefit from lateral yielding is the diminution of side-slip. Side-slip will begin as soon as the lateral force called out between the wheel and the road at the ground-point exceeds a certain limiting amount. Lateral yielding eases off the suddenness of lateral impulses, thus keeping down the maximum amount of lateral force; and this is precisely what is required for preventing side-slip.

In some of the driving-wheels which the author has constructed the hub is allowed to project much farther on the side remote from the driving-chain than on the side next the chain, in order to permit the combination of a wide hub with a narrow width between the pedals. Weaker springs are used on the projecting side than on the other side. This unsymmetrical arrangement is not found to interfere with the ease of steering.

SECTION H.—ANTHROPOLOGY.

PRESIDENT OF THE SECTION—Sir W. H. FLOWER, K.C.B., LL.D., Sc.D., F.R.S.

THURSDAY, AUGUST 9.

The President delivered the following Address:—

IT is not usual for the President of a Section of this Association to think it necessary to give any explanation of the nature of the subjects brought under its cognisance, or to emphasise their importance among other branches of study; but so general is the ignorance, or at all events vagueness of information, among otherwise well-instructed persons, that I will ask your permission to devote the short time accorded to me before the actual work of the Section begins to giving some account of the history and present position of the study of Anthropology in this country, and especially to indicate what this Association has done in the past, and is still doing, to promote it.

It is only ten years since the Section in which we are now taking part acquired a definite and assured position in the organisation of the Association. The subject, of course, existed long before that time, and was also recognised by the Association, though with singular vicissitudes of fortune and position. It first appeared officially in 1846, when the 'Ethnological sub-Section of Section D' (then called 'Zoology and Botany') was constituted. This lasted till 1851, when Geography parted company from Geology, with which it had been previously associated in Section C, and became Section E, under the title of 'Geography and Ethnology.' In 1866 Section D changed its name to 'Biology,' with Physiology and Anthropology (the first occurrence of this word in our official proceedings) as separate 'Departments;' but the latter does not seem to have regained its definite footing as a branch of Biological Science until three years later (1869), when Section E, dropping Ethnology from its title, henceforward became Geography alone. The Department for the first two years (1869 and 1870) was conducted under the title of Ethnology, but in 1871 it resumed the name of Anthropology, given it in 1866, and it flourished to such an extent, attracting so many papers and such large audiences, that it was finally constituted into a distinct Section, to which the letter H was assigned, and which had its first session at the memorable meeting at Montreal, exactly ten years ago, under the fitting and auspicious presidency of Dr. E. B. Tylor.

The history of the gradual recognition of Anthropology as a distinct subject by this Association is an epitome of the history of its gradual growth, and the gradual recognition of its position among other sciences in the world at large, a process still in operation and still far from complete. Although the word Anthropology had certainly existed, but used in a different sense, it was not till well into the middle of the present century that it, or any other word, had been thought of to designate collectively the scattered fragments of various kinds of knowledge bearing upon the natural history of man, which were beginning to be collected from so many diverse sources. Indeed, as I have once before upon a similar occasion remarked, one of the great difficulties with regard to making

Anthropology a special subject of study, and devoting a special organisation to its promotion, is the multifarious nature of the knowledge comprehended under the title. This very ambition, which endeavours to include such an extensive range of subjects, ramifying in all directions, illustrating and receiving light from so many other sciences, appears often to overleap itself, and give a looseness and indefiniteness to the aims of the individual or the institution proposing to cultivate it. The old term Ethnology, or the study of peoples or races, has a limited and definite meaning. It treats of the resemblances and modifications of the different groups of the human species in their relations to each other, but Anthropology, as now understood, has a far wider scope. It treats of mankind as a whole. It investigates his origin and his relations to the rest of the universe. It invokes the aid of the sciences of zoology, comparative anatomy and physiology, in its attempts to estimate the distinctions and resemblances between man and his nearest allies, and in fixing his place in the scale of living beings. In endeavouring to investigate the origin and antiquity of man, geology must lend its assistance to determine the comparative ages of the strata in which the evidences of his existence are found, and researches into his early history soon trench upon totally different branches of knowledge. In tracing the progress of the race from its most primitive condition, the characteristics of its physical structure and relations with the lower animals are soon left behind, and it is upon evidence of a kind peculiar to the human species, and by which man is so pre-eminently distinguished from all other living beings, that our conclusions mainly rest. The study of the works of our earliest known forefathers—'prehistoric archæology' as it is commonly called—is now almost a science by itself. It investigates the origin of all human culture, endeavours to trace to their common beginning the sources of our arts, customs, and history. The difficulty is, what to include and where to stop; as, though the term prehistoric may roughly indicate an artificial line between the province of the anthropologist and that which more legitimately belongs to the archæologist, the antiquary, and the historian, it is perfectly evident that the studies of the one pass insensibly into those of the others. Knowledge of the origin and development of particular existing customs throws immense light upon their real nature and importance; and conversely, it is often only from a profound acquaintance with the present or comparatively modern manifestations of culture that we are able to interpret the slight indications afforded us by the scanty remains of primitive civilisation.

It is considerations such as these that have caused the gradual introduction of the term Anthropology as a substitute for Ethnology which I have traced in the history of this Association, and which is seen in other organisations for the cultivation of our science.

The first general association for the study of man in this country was founded in 1843, under the name of the 'Ethnological Society' (three years, therefore, before the Ethnological sub-Section of Section D of this Association). It did excellent work for many years under that title, but partly from personal considerations, and partly from a desire to undertake a wider and somewhat different field of research, another and in some senses a rival society, which adopted the name of 'Anthropological,' was founded in 1863. For some years these existed side by side, each representing in its most active supporters different schools of the science. This arrangement naturally involved a waste of strength, and it was felt that the interests of the subject would be promoted by an amalgamation of the two societies. Many difficulties, chiefly, as is usual in such cases, of a personal nature, had to be overcome, one of the principal being the selection of a name for the united society. It was generally felt that 'Anthropological' would be most appropriate, but the members of the old Ethnological Society could not bring themselves absolutely to sink the fact of their priority of existence, and all that they had done for science for so many years, by merging their society into that of their younger and active rivals; so after much discussion a compromise was effected, and the new organisation which arose from the coalescence of the two societies adopted the rather cumbrous title of 'Anthropological Institute of Great Britain and Ireland.' This was in 1871, and since that period, the *Society*, as it is to all intents and purposes both in structure and function, has pursued a peaceful and useful course of existence, holding meetings at stated periods throughout the session, at which papers are read and subjects of interest to anthropologists exhibited and discussed. It has also published a quarterly journal, which has been the principal means in this country of communicating new information upon such subjects. The Institute has for twenty-three years performed this duty in a business-like and unostentatious manner, the only remarkable circumstance connected with its history being the singular want of interest taken by the outside world in its proceedings, considering their intrinsic importance to society, especially in an empire like ours, which more than any other affords a field for the study of man, under almost every aspect of diversity of race, climate, and culture. At the present time it numbers only 305 ordinary members, whose subscriptions afford barely sufficient means to maintain the library and journal in a state of efficiency. The kindred Geographical and Zoological Societies have respectively 3,775 and 2,985 fellows, so far greater is the interest taken in the surface of the earth itself, and in the animals which dwell upon it, than in its human inhabitants!

Societies similar in their object to that the history of which I have just sketched have sprung up, and are now in a more or less flourishing condition, in every civilised country of the world. But confining our retrospect to our own country, we may take a glance at what has been done in recent years to promote the organised study of Anthropology otherwise than by means of this Association (to which I shall refer again later) or the Society of which I have just spoken.

One of the most potent means of registering facts, and making them available for future study and reference, is to be found in actual collections of tangible objects. To very considerable branches of anthropological science this method of fixing the evidence upon which our knowledge of the subject is based is particularly applicable. These branches are mainly two, very distinct from each other, and each representing one of the principal sides in which Anthropology presents itself.

I. Collections illustrating the physical structure of man, and its variations in the different races.

II. Collections showing his characteristic customs and methods of living, his arts, arms and costumes, as developed under different circumstances and also modified by different racial conditions.

It is very rarely that these two are combined in one general arrangement, and they are almost always studied apart, the characteristics of mind, the general education and special training which are required for the successful cultivation of either being rarely combined in a single individual; and yet the complete history of any race of mankind, especially with regard to its relation to other races, must be based upon a knowledge both of its physical and psychical characteristics, and customs, habits, language, and tradition largely help, when anatomical characters fail to separate and define.

The anthropological museums of this country, as well as elsewhere, are [illegible] all of recent growth, and they are making progress everywhere with steadily accelerating speed. This cannot be better illustrated than in the place where we are [illegible] at the present time. Many of those who are now in this room can remember [illegible] when the materials for the study of either branch of the subject in Oxford were [illegible] absolutely non-existent. I can myself recall the time when the site of the handso[illegible] building which now houses the scientific treasures of the University was a bar[illegible] field. All who know the modern history of Oxford must be aware that it was [illegible] mainly owing to the enthusiastic zeal and steady perseverance in the cause of scientific education of one who is happily still among us, the veteran Regius Professor of Medicine, Sir Henry Acland, that that building was erected. The possession of a well-selected and representative collection illustrating the anatomical characters of the human species is chiefly owing to the energetic labours of [illegible] Professor Rolleston, one of the brightest and noblest of Oxford's sons, a man of [illegible] whom I cannot speak without feelings of the strongest affection and most pro[illegible]found regret for his untimely loss to the University and the world.

The collection illustrating the arts and customs of primitive people the

University owes to the ingenuity and munificence of General Pitt-Rivers, who not only provided the material on which it is based, but also the original and unique scheme of arrangement, which adds so greatly to its value as a means of education, and is so admirably calculated to awaken an interest in the subject, even in the minds of the most superficial visitor. In speaking thus of the method of displaying the Pitt-Rivers collection, I must not be supposed to imply any disparagement of others arranged on different plans. Provided there is a definite and consistent arrangement of some sort, it is well that there should be a diversity in the treatment of different collections, and for such a vast and exhaustive collection as that under the care of Sir Wollaston Franks, at the British Museum, the geographical system which has been adopted is certainly the best. In it every specimen of whatever nature at once finds a place, in which it can at any time be discovered and recognised.

In referring to our great national collection, I cannot refrain from saying that there seemed till lately to be only one element wanting to make it all that could be desired, and that was space, not only for the proper preservation and exhibition of what it already contains, but also for its inevitable future expansion. The provision in this respect was totally inadequate to do justice to the importance of the subject. Happily this consideration will be no longer a bar to the development of the collection. The provident action of the authorities of the Museum, aided by the liberality of the Duke of Bedford and the wisdom of Her Majesty's Government, has secured for many years to come the necessary room for the expansion of the grandest of our national institutions.

More modern even than museums has been the introduction of any systematic teaching of Anthropology into this country. This is certainly most remarkable, considering that there is no nation to which the subject is of such great importance. Its importance to those who have to rule—and there are few of us now who are not called upon to bear our share of the responsibilities of government—can scarcely be overestimated in an empire like this, the population of which, as I have just said, is composed of examples of almost every diversity under which the human body and mind can manifest itself. The physical characteristics of race, so strongly marked in many cases, are probably always associated with equally or more diverse characteristics of temper and intellect. In fact, even when the physical divergences are weakly shown, as in the different races which contribute to make up the home portion of the Empire, the mental and moral characteristics are still most strongly marked. As the wise physician will not only study the particular kind of disease under which his patient is suffering before administering the approved remedies for such disease, but will also take into careful account the peculiar idiosyncrasy and inherited tendencies of the individual, which so greatly modify both the course of the disease and the action of remedies, so it is absolutely necessary for the statesman who would govern successfully, not to look upon human nature in the abstract and endeavour to apply universal rules, but to consider the special moral, intellectual, and social capabilities, wants, and aspirations of each particular race with which he has to deal. A form of government under which one race would live happily and prosperously may to another be the cause of unendurable misery. All these questions, then, should be carefully studied by those who have any share in the government of people belonging to races alien to themselves. A knowledge of their special characters and relations to one another has a more practical object than the mere satisfaction of scientific curiosity; it is a knowledge upon which the happiness and prosperity or the reverse of millions of our fellow-creatures may depend. The ignorance often shown upon these subjects, even in so select an assembly as the House of Commons, would be ludicrous if it were not liable to lead to disastrous results.

Now let us consider what, amid all the complex, diverse, and costly machinery of education in this country, is being done to satisfy the demands for such knowledge. We may say at once, as regards all institutions for primary and secondary education, absolutely nothing. The inhabitants of the various regions of our own earth are treated with no more consideration and interest in all such institutions than if they lived on the moon or the planets. We must turn straight to the higher intellectual centres in the hope of finding any anthropological teaching. Here, at Oxford, if anywhere, we may expect to find it, and here, first among the British Universities, have we seen, since the year 1883, among the list of the subjects taught the word 'Anthropology;' but the teacher, though one of the most learned of men in the subject the country has produced, still only bears the modest title of 'Reader.' A professorship of Anthropology does not exist at present in the British Isles, and even here the subject, though recognised as a 'special,' offers little field for distinction in the examinations for degrees, and has therefore never been taken up in a thorough manner by students. Dr. Tylor's lectures must, however, have done much to have spread an intelligent interest in some branches of Anthropology, and have proved a valuable complement to the Pitt-Rivers collection, as have also the courses which have been given by Mr. Henry Balfour upon the arts of mankind and their evolution, one of which I am glad to see is announced among the advantages offered to the University Extension students at present with us. Physical Anthropology has also been taken up by Professor A. Thomson, who, I understand, gives instructive lectures upon it, open to the members of his class of human anatomy. At the opposite end almost of the subject must be mentioned the extension and organisation of the Ashmolean Museum under the care of Mr. Arthur J. Evans, which has a bearing upon some branches of Anthropology, and the foundation of the Indian Institute under the auspices of Sir Monier Monier-Williams, which must give an impetus to the study of the characteristics of the races of our great Empire in the East. Last, but by no means least in its bearing upon the origin, divisions, and diffusion of races, is the world-famous linguistic work of Professor Max Müller and Professor Sayce, both of whom have presided over this Section at former meetings of the Association.

Of the sister University I wrote thus in 1884: 'In Cambridge there are many hopeful signs. The recently appointed Professor of Anatomy, Dr. Macalister, is known to have paid much attention to Anatomical Anthropology, and has already intimated that he proposes to give instruction in it during the summer term. An Ethnological and Archæological Museum is also in progress of formation, which, if not destined to rival that of Oxford, already contains many objects of great value, and a guarantee of its good preservation and arrangement may be looked for in the appointment of Baron Anatole von Hügel as its first curator.'

Ten years have passed, and it is satisfactory to know that the teaching of Anthropology has not only been fairly established, but the subject has also found a place in the scheme of University examination. The learned Professor of Human Anatomy continues to take a wide view of his functions, giving a course during the Easter term on the methods of Physical Anthropology, and also museum demonstrations on craniometry and osteometry, by the aid of a greatly increased and continually augmenting collection of specimens. Those students who take anatomy as their subject for the second part of the Natural Science Tripos have both paper work and practical examination in Anthropology, each man having a skull placed in his hands of which he is expected to make a complete diagnostic description. For the first part of the tripos each candidate has one or more questions on the broad general principles of the subject. Professor Macalister informs me that he has always at least six men who go through a very thorough practical course with their own hands. There has also lately been established a course of lectures on the Natural History of the Races of Man, delivered during the Michaelmas and Lent terms by Dr. Hickson, of Downing College, and Baron von Hügel gives a course of museum demonstrations on the weapons, ornaments, and other objects in the Ethnological Museum, which is open to all students, and of which many take advantage.

In London, owing to the chaotic condition of all forms of higher instruction, which has been brought so prominently into notice by the universal demand for a teaching University (an aspiration which the labours of the late Gresham Commission certainly seem to have brought nearer to realisation than ever appeared possible before), all systematic anthropological teaching has been entirely neglected. The great collections to which I have already alluded, that of arts and customs at the British Museum, and that of osteological specimens at the Royal College of

Surgeons, have by their steady augmentation done valuable service in preserving a vast quantity of material for future investigation and instruction, and students have at present all reasonable facilities for pursuing their own researches in them. Lectures have never formed any part of the official programme of the British Museum, but at the College of Surgeons it is otherwise, and though the contents of the collections are specially indicated as the subject on which they should be delivered, for the last ten years at least, Anthropology, notwithstanding the magnificent material at hand for its illustration, has had no place in the annual syllabus. It is also entirely ignored in the examination scheme of the University of London, an institution which prides itself as being on a level with modern educational requirements; and the managers of the new Imperial Institute, casting about in all directions for some worthy object to occupy their energies and their spacious buildings, do not appear to have taken into serious consideration the value to the world and the appropriateness to their original design of a great central school of Anthropology, from which might emanate a full and satisfying knowledge of the characteristics of all the various races of which the Empire is composed.

In Scotland the recent Universities Commission has recognised Physical Anthropology as a branch of human anatomy in their scheme for graduation in pure science, the examination on this subject embracing a knowledge of race characters as found in the skull and other parts of the skeleton, in the skin, eyes, hair, features, and the external configuration of the body generally; the methods of anthropometrical measurement, both of the living body and the skeleton; the possible influence of use and of external surroundings in producing modifications in the physical characters of man, and an acquaintance with the 'types' of mankind and the structural relations of man to the higher mammals. These regulations came into operation in the University of Edinburgh in 1892, and in accordance with them Professor Sir William Turner delivers a special course of twenty-five lectures on Physical Anthropology, and in addition ten practical demonstrations on osteometry. The museum under his charge has greatly increased of late in number and value of the specimens. But 'Human Anatomy, including Anthropology,' being only one of a series of nine subjects in any three or more of which a final science examination on a higher standard has to be passed, there is not at present any considerable number of students who take it up, and the other Scotch Universities have not yet thought it necessary to establish distinct courses of Physical Anthropology, although it is becoming more and more a regular part of the anatomical teaching to advanced students.

For the following account of what is being done to further the knowledge of our subject in the sister isle I am indebted to Professor D. J. Cunningham. The only place in Ireland where anthropological work is done is Trinity College. For many years those in charge of the museum have been collecting skulls, and they were fortunate in obtaining the greater part of Sir William Wilde's collection. To these great additions have been recently made, principally in the form of Irish crania from different districts. All the anthropological specimens are lodged in one large room, which is also used as an anthropometric laboratory. Though there has never been any systematic teaching of Anthropology in Trinity College, Dr. C. R. Browne (Professor Cunningham's able assistant), who takes charge of the laboratory, attends for two hours on three days a week, and gives demonstrations in anthropological methods to any students who are interested in the subject. The laboratory was opened in June 1891, the instruments being provided by a grant from the Royal Irish Academy, and about 500 individuals have already been measured, the greater number of them students of the College. This is, however, only part of the work carried out by the laboratory. Every year the instruments are taken to some selected district in Ireland, and a systematic study of the inhabitants is made. The Aran Islands, and also the islands of Inishboffin and Inishshark, have been already worked out, and this year excursions are organised to Kerry, to a district in Wicklow, and to another in the West of Ireland. The Academy makes yearly grants to the Committee for carrying on this work, the results of which have been published in admirable memoirs by Professor A. C. Haddon and Dr. C. R. Browne. The Science and Art Museum in Dublin, under the direction of Dr. V. Ball, contains a small collection, arranged with a view to general instruction, showing by means of skulls and casts the physical characteristics of the different races of man, those of each race being explained by a short printed label, and its range shown on a map.

Though the development of anthropological science has thus not been greatly advanced, in this country at least, by means of endowments, or by aid of the State or, till very recently, by our great scholastic institutions, but has been mainly left to the unorganised efforts of amateurs of the subject, its progress in recent years has been undeniably great. I will give an instance of the strides that have been made in one of its most important branches.

Physical or Anatomical Anthropology, or the study of the modifications of the human body under its various aspects, the modifications dependent upon sex and age, the modifications dependent upon race, and those dependent upon individual variability, studied not many years ago in a vague and loose manner, has gradually submitted to a rigorous and, therefore, strictly scientific method of treatment. The generalities which were formerly used to express the differences that were recognised between the various subjects compared with each other have been replaced by terms conveyed in almost mathematical precision. No one acquainted with the history of the development of this branch of Anthropology can fail to recognise how much it was accelerated by the genius of Broca, and the school which he established in France, although all cultivated nations are now vying with each other in the practice of exactitude in anthropological research, and the time seems rapidly approaching when a common agreement will be arrived at, by which all the observations which may be made, under whatever diverse circumstances, and by whatever different individuals, will be available for comparison one with another.

This branch of our science has received the name of 'Anthropometry.' Although, as the name implies, measurement is one of its principal features, it includes such other methods of comparison as can be reduced to a definite standard, or to which definite tests can be applied, such as the colour of the hair, eyes, and complexion, the form of the ear and nose. The great desiderata that have been sought for, and gradually attained, in measuring either the skeleton or the living person have been two in number: 1. Exact definition of the points between which the measurements should be taken. 2. Exact methods and instruments of measurement. In both these cases the object looked for has been not only that the measurements taken by the same observer at different times and under different circumstances should coincide, but also that those taken by different observers should be comparable. These requirements seem so simple and natural at first sight that the majority of persons whom I am addressing will wonder that I should allude to them. Only those who are seriously occupied, or perhaps I should rather say, only those who were seriously occupied a few years ago, with the endeavour to solve these problems can have any idea of their difficulty. The amount of time and labour that has been spent upon them is enormous, but the result has, I think, been quite commensurate with it.

We have attained at last to methods of measurement and standards of comparison which, in the hands of persons of ordinary intelligence, and with a moderate amount of training, will give data which may be absolutely depended upon. From these we hope to be able to formulate accurate information as to the physical conformation of all the groups into which mankind is divided, and so gradually to arrive at a natural classification of those groups, and a knowledge of their affinities one to another.

But the exact methods of modern Anthropometry are not only important on account of the aid they give in studying the race characteristics of man. As has so often happened when scientific observation has been primarily carried out for its own sake, it ultimately leads to practical applications undreamt of by its earlier cultivators. The application of Anthropometry not to the comparison of races, but to elucidate various social problems—as the laws of growth, of heredity, of comparative capacities of individuals within a community, and the effects of different kinds of education and occupation, as worked out first by Quetelet in

Belgium, and subsequently by Francis Galton, Roberts, and others in this country—and its still more concrete application as an aid in administering justice by methods perfected by Bertillon in France, are striking illustrations of the practical utility of labours originally undertaken under the influence of devotion to science pure and simple.

The importance of being able to determine the identity of an individual under whatever circumstances of disguise he may be presented for examination has, of course, long been apparent to all who have had anything to do with the administration of the criminal law, and rough and ready methods of recognition, depending mainly upon the more or less acute faculty of perception and recollection of differences and resemblances, possessed by the persons upon whom the duty of identification has devolved, have long been in operation. The general conformation, height, form of features, and colour of complexion, hair, and eyes, have also been noted. Much additional assistance has been obtained by the registration of definite physical characteristics, the results either of natural conformation, or of injury, such as mutilations, tattoo-marks, and scars, inflicted by accident or design. The application of one of the most important scientific discoveries of the age, photography, was eagerly seized upon as a remedy for the difficulties hitherto met with in tracing personal identity, and enormous numbers of photographs were taken of persons, the peculiarities of whose career led them to fall into the hands of the police, and who were likely to be wanted again on some future occasion. No doubt much help has been derived from this source, but also much embarrassment. Even among photographic portraits of one's own personal friends, taken under most favourable circumstances, and with no intention of deception, we cannot often help exclaiming how unlike they are to the person represented. With portraits of criminals, the varying expression of the face, changes in the mode of wearing the hair and beard, differences of costume, the effects of a long lapse of time, years perhaps passed in degradation and misery, may make such alterations that recognition becomes a matter at least of uncertainty. That photographs are extremely valuable as aids to identification, when their true position in the process is recognised, cannot be doubted; but as a primary method they have been found to be quite inapplicable, owing partly to the causes just indicated, but mainly to the difficulty, if not impossibility, of classifying them. The enormous expenditure of time and trouble that must be consumed in making the comparison between any suspected person and the various portraits of the stock which accumulates in prison bureaus may be judged of from the fact that, in Paris alone, upwards of 100,000 such portraits of persons interesting to the police have been taken in a period of ten years.

The primary desideratum in a system of identification is a ready means of classifying the data upon which it is based. To accomplish this is the aim of the Bertillon system. Exact measurements are taken between certain well-known and fixed points of the bony framework of the body, which are known not to change under different conditions of life. The length and breadth of the head, the length of the middle finger, the length of the foot, and the length of the forearm, are considered the best, though others are added for greater certainty, as the height, span of arms, length of ear, colour of eyes, &c. All these particulars of every individual examined are recorded upon a card, and by dividing each measurement into three classes, long, medium, and short, and by classifying the various combinations thus obtained, the whole mass of cards, kept arranged in drawers in the central bureau, is divided up into groups, each containing a comparatively small number, and therefore quite easily dealt with. When the card of a new prisoner is brought in, a few minutes suffice to eliminate the necessity of comparison with any but one small batch, which presents the special combination. Then photographs and other means of recognition, as distinctive marks and form of features, are brought into play, and identification becomes a matter of certainty. On the other hand, if the combination of measurements upon a new card does not coincide with any in the classed collection in the bureau, it is known with absolute certainty that the individual being dealt with has never been measured before.

One of the most striking results of the introduction of this system into France has been that, since it has been brought fully into operation, a large proportion of old offenders, knowing that concealment is hopeless, admit their identity at once, and save a world of trouble and expense to the police by ceasing to endeavour to conceal themselves under false names.

Various representations upon this subject have been addressed to the Home Secretary of our own Government during the last few years, and among others one from the Council of this Association, which originated in a resolution of this Section, adopted by the General Committee at the meeting at Edinburgh in 1892, to this effect:

'That the Council be requested to draw the attention of Her Majesty's Government to the Anthropometric Method for the measurement of criminals, which is successfully in operation in France, Austria, and other Continental countries, and which has been found effective in the identification of habitual criminals, and consequently in the prevention and repression of crime.'

In consequence of these representations a Committee was appointed, on Oct. 21, 1893, by Mr. Asquith, consisting of Mr. C. E. Troup, of the Home Office, Major Arthur Griffiths, Inspector of Prisons, and Mr. Melville Leslie Macnaghten, Chief Constable in the Metropolitan Police Force, with Mr. H. B. Simpson, of the Home Office, as secretary, 'to inquire (*a*) into the method of registering and identifying habitual criminals now in use in England; (*b*) into the "Anthropometric" system of classified registration and identification in use in France and other countries; (*c*) into the suggested system of identification by means of a record of finger marks: to report whether the anthropometric system or the finger-mark system can with advantage be adopted in England either in substitution for or to supplement the existing methods; and, if so, what arrangements should be adopted for putting them into practice, and what rules should be made under Section 8 of the Penal Servitude Act, 1891, for the photographing and measuring of prisoners.'

The Report of this Committee, with minutes of evidence and appendices, was issued as a Parliamentary Blue-book in March last, and not only contains a lucid and concise description of the methods of identification already in use in this country, but also most striking testimony from impartial but well-qualified persons to the value of a more scientific mode of dealing with the subject. No pains seem to have been spared to obtain, both by personal observation and by the examination of competent witnesses, a thorough knowledge of the advantages of the Bertillon system as practised in France, and the result has been the recommendation of that system, with certain modifications, for adoption in this country, with the addition of the remarkably simple, ingenious, and certain method of personal identification first used in India by Sir William Herschel, but fully elaborated in this country by Mr. Francis Galton, that called the 'finger-mark system,' about which I shall have a few more words to say presently.

With the concluding words of the Committee's Report I most fully concur: 'We may confidently anticipate that, if fairly tried, it will show very satisfactory results within a few years in the metropolis; but the success of its application in the country generally will depend on the voluntary co-operation of the independent county and borough police forces. This, we feel sure, will not be withheld. When the principles of the system are understood and its usefulness appreciated we believe it will not only save much time and labour to the police in the performance of an important duty, but will give them material assistance in tracing and detecting the antecedents of the guilty, and will afford, so far as its scope extends, an absolute safeguard to the innocent.'

It is very satisfactory to be able to add that in the House of Commons on June 26, in answer to a question from Colonel Howard Vincent, the Home Secretary announced that the recommendations of the Committee had been adopted; and that, in order to facilitate research into the judicial antecedents of international criminals, the registers of measurements would be kept on the same plan as that adopted with such success in France, and also in other Continental countries.

I have just mentioned the 'finger-mark system,' and of all the various developments of Anthropology in recent times none appears to me more interesting than the work done by Mr. Galton upon this subject; for though, as indicated above, he is not quite the first who has looked into the question or shown its practical application in personal identification, he has carried his work upon it far beyond that of any of his predecessors, both in its practical application and into regions of speculation unthought of by anyone else. Simple and insignificant as in the eyes of all the world are the little ridges and furrows which mark the skin of the under-surface of our fingers, existing in every man, woman, and child born into the world, they have been practically unnoticed by everyone until Mr. Galton has shown, by a detailed and persevering study of their peculiarities, that they are full of significance, and amply repay the pains and time spent upon their study. It is not to be supposed that all the knowledge that may be obtained from a minute examination of them is yet by any means exhausted, but they have already given important data for the study of such subjects as variation unaffected by natural or any other known form of selection, and the difficult problems of heredity, in addition to their being one of the most valuable means hitherto discovered of fixing personal identity.

As an example of the importance of some ready method to prove identity, apart from its application to the detection, punishment, and prevention of crime, to which I have already referred, I may recall to your recollection that remarkable trial which agitated the length and breadth of the land rather more than twenty years ago; a trial which occupied so many months of the precious time of our most eminent judges and counsel, and cost the country, as well as several innocent persons—I am afraid to say how many—thousands of pounds, all upon an issue which might have been settled in two minutes if Roger Tichborne, before starting on his voyage, had but taken the trouble to imprint his thumb upon a piece of blackened paper. It is wonderful to me, on reading again the reports of the trial, to see how comparatively little attention was paid by counsel, judge, or jury, to the extremely different physical characteristics of the two persons claimed to be identical, but which were so strongly marked that they ought to have disposed of the claim, without any hesitation, at the very opening of the case. It was not until the 102nd day of the first trial that the attention of the jury was pointedly called to the fact that it was known that Sir Roger Tichborne had been tattooed on the left arm with a cross, anchor, and a heart, and that the Claimant exhibited no such marks. When this was clearly brought out and proved, the case broke down at once. The second trial for perjury occupied the court 188 days, the Lord Chief Justice's charge alone lasting eight days. The issues were, however, more complex than in the first trial, as it was not only necessary to prove that the Claimant was not Tichborne, but also to show that he was someone else. I feel convinced that at the present time the greater confidence that is reposed in the methods of Anthropometry or close observance of physical characters, and in the persistence of such characters through life, would have greatly simplified the whole case; and I would strongly recommend all who have nothing about their lives they think it expedient to conceal to place themselves under the hands of Mr. Galton, or one of his now numerous disciples, and get an accurate and unimpeachable register of all those characteristics which will make loss of identity at any future period a sheer impossibility.

Partly with this object in view the Association has, for several years past, during each of its meetings, opened, under the superintendence of Dr. Garson, an Anthropometric Laboratory, on the plan of the admirable institution of the same name which has been carried on in the South Kensington Museum since the beginning of the year 1888, under the direction and at the sole cost of Mr. Francis Galton, in which up to the present time more than 7,000 complete sets of measurements have been made and recorded. The results obtained at the British Association meetings have been published in the Annual Reports of the Association, and, though on a smaller scale than Mr. Galton's, the operations of the laboratory have been most useful in diffusing a knowledge of the value of anthropometric work, and of the methods by which it is carried on.

For many years an 'Anthropometric' Committee of the Association, in which the late Dr. W. Farr, Mr. F. Galton, Mr. C. Roberts, Dr. Beddoe, Sir Rawson Rawson, and others, took an active part, was engaged in collecting statistical information relating to the physical characters, including stature, weight, chest-girth, colour of eyes and hair, strength of arms, &c., of the inhabitants of the British Isles; and their reports, illustrated by maps and diagrams, were published in the annual volume issued by the Association. This Committee terminated its labours in 1883, although, as was fully acknowledged in the concluding report, the subject was by no means completely exhausted.

A great and important work which the Association has now in hand, in some sense a continuation of that of the Anthropometric Committee, though with a more extended scope of operation, is the organisation of a complete ethnographical survey of the United Kingdom based upon scientific principles. In this work the Association has the co-operation of the Society of Antiquaries of London, the Folk-lore Society, the Dialect Society, and the Anthropological Institute. Representatives of these different bodies have been formed into a Committee, of which Mr. E. W. Brabrook is now chairman. It is proposed to record in a systematic and uniform character for certain typical villages and the neighbouring districts—(1) the Physical Types of the Inhabitants, (2) their current Traditions and Beliefs, (3) Peculiarities of Dialect, (4) Monumental and other Remains of Ancient Culture, and (5) Historical Evidence as to Continuity of Race. The numerous Corresponding Societies of the Association scattered over various parts of the country have been invited to co-operate, and the greater number of them have cordially responded, and special local committees have been formed in many places to carry out the work.

The result of a preliminary inquiry as to the places in the United Kingdom which appeared especially to deserve ethnographic study, mainly on account of the stationary nature of the population for many generations back, was given in the first Report of the Committee presented at the Nottingham meeting of the Association last year, in which it was shown that in the British Isles there are more than 250 places which, in the opinion of competent authorities, would be suitable for ethnographic survey, and in which, notwithstanding the rapid changes which have taken place during the last fifty years in all parts of the country, much valuable material remains for the Committee to work upon. Without doubt, as interest in the subject is aroused, this number will be greatly increased.

A most important step in securing the essential condition that the information obtained should be of the nature really required for the purpose, and that the records of different observers should be as far as possible of equal value and comparable one with another, has been the compilation of a very elaborate and carefully prepared schedule of questions and directions for distribution among those who have signified their willingness to assist, and as a guarantee that the answers obtained to the questions in the schedules will be utilised to the fullest extent, certain members of the Committee specially qualified for each branch of the work have undertaken to examine and digest the reports when received.

It may be remarked in passing that the Anthropological Society of Paris has within the past year formed a Commission of its members to collect in a systematic manner the scattered data which, when united and digested, shall form 'une anthropologie véritablement nationale de la France,' and has issued a circular with schedules of the required observations. These are, however, at present limited to the physical characters of the population.

Among the many services rendered to the science of Anthropology by the British Association, not the least has been the aid it has afforded in the publication of that most useful little manual entitled 'Notes and Queries on Anthropology,' of which the first edition was brought out exactly twenty years ago (1874), under the supervision and partly at the expense of General Pitt-Rivers. Since that time the subject has made such great advances that a second edition, brought up to the requirements of the present time, was urgently called for. A Committee of the British Association, appointed to consider and report upon the best means of doing this, recommended that the work should be placed in the hands of the Anthropological Institute of Great Britain and Ireland. This recommendation was approved by the Association, and grants amounting to 70*l*. were made to assist in defraying the cost of publication. The Council of the Anthropological Institute appointed a Committee of its members to undertake the revision of the different subjects, with Dr. J. G. Garson and Mr. C. H. Read as editors respectively of the two parts into which it is divided. The work was published at the end of the year 1892, and is invaluable to the traveller or investigator in pointing out the most important subjects of inquiry, and in directing the observations he may have the means of making into a methodical and systematic channel.

Besides those I have already mentioned, the Association has aided many other anthropological investigations by the appointment of Committees to carry them out, and in some cases by the more substantial method of giving grants from its funds, and by defraying the cost of publication of the results in its journal. Among these I may specially mention the series of very valuable Reports upon the Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada, drawn up by Mr. Horatio Hale, Dr. F. Boas, and others, the importance of which has been recognised by the Canadian Government in the form of a grant in aid of the expenses.

Another very interesting investigation into the Habits, Customs, Physical Characteristics, and Religion of the Natives of Northern India, initiated by Mr. H. H. Risley, and carried on under his supervision by the Indian Government, though it has received little more than moral support from the Association, may be mentioned here on account of the illustration it affords of the value of exact anthropometric methods in distinguishing groups of men. Although a practised eye can frequently tell at a glance the tribe or caste of a man brought before it for the first time, the special characters upon which the opinion is based have only lately been reduced to any definite and easily comparable method of description. In Mr. Risley's examination, the nose, for instance (which I have always held to be one of the most important of features for classificatory purposes), instead of being vaguely described as broad or narrow, is accurately measured, and the proportion of the greatest width to the length (from above downwards), or the 'nasal index,' as it is termed (though it must not be confounded with the nasal index as defined by Broca upon the skull), gives a figure by which the main elements of the composition of this feature in any individual may be accurately described. The average or mean nasal indices of a large number of individuals of any race, tribe, or caste offer means of comparison which bring out most interesting results. By this character alone the Dravidian tribes of India are easily separated from the Aryan. 'Even more striking is the curiously close correspondence between the gradations of racial type indicated by the nasal index and certain of the social data ascertained by independent inquiry. If we take a series of castes in Bengal, Behar, or the North-Western Provinces, and arrange them in the order of the average nasal index, so that the caste with the finest nose shall be at the top, and that with the coarsest at the bottom of the list, it will be found that this order substantially corresponds with the accepted order of social precedence. The casteless tribes—Kols, Korwas, Mundas, and the like—who have not yet entered the Brahmanical system, occupy the lowest place in both series. Then come the vermin-eating Musuhars and the leather-dressing Chamárs. The fisher castes of Bauri, Bind, and Kewat are a trifle higher in the scale; the pastoral Goala, the cultivating Kurmi, and a group of cognate castes—from whose hands a Brahman may take water—follow in due order; and from them we pass to the trading Khatris, the landholding Bábhans, and the upper crust of Hindu society. Thus, it is scarcely a paradox to lay down as a law of the caste organisation in Eastern India that a man's social status varies in inverse ratio to the width of his nose.' The results already obtained by this method of observation have been so important and interesting that it is greatly to be hoped that the inquiry may be extended throughout the remainder of our Indian Empire.

But for want of time I might here refer to the valuable work done in relation to the natives of the Andaman Islands, a race in many respects of most exceptional interest, first by Mr. E. H. Man, and more recently by Mr. M. V. Portman, and for the same reason can scarcely glance at the great progress that is being made in anthropological research in other countries than our own. The numerous workers on this subject in the United States of America are, with great assistance from the Government, very properly devoting themselves to exploring, collecting, and publishing, in a systematic and exhaustive manner, every fact that can still be discovered relating to the history, language, and characters of the aboriginal population of their own land. They have in this a clear duty set before them, and they are doing it in splendid style. I wish we could say that the same has been done with all the native populations in various parts of the world which have been, to use a current phrase, 'disestablished and disendowed' by our own countrymen. We are, however, now, as I have shown, not altogether unmindful of what is our duty to posterity in this respect; a duty, perhaps, more urgent than that of any other branch of scientific investigation, as it will not wait. It must be done, if ever, before the rapid spread of civilised man all over the world, one of the most remarkable characteristics of the age in which we live, has obliterated what still remains of the original customs, arts, and beliefs of primitive races; if, indeed, it has not succeeded—as it too often does—in obliterating the races themselves.

The following Reports and Papers were read:—

1. *The Report of the Anthropometric Laboratory Committee.*

See Reports, p. 444.

2. *The Report of the Ethnographical Survey Committee.*

See Reports, p. 419.

3. *The Report of the Committee on Anthropometry in Schools.*

See Reports, p. 439.

4. *On the Diffusion of Mythical Beliefs as Evidence in the History of Culture.* *By* EDWARD B. TYLOR, *D.C.L., LL.D., F.R.S.*

The purpose of this communication was to illustrate and systematise the use of correspondence in culture as means of tracing lines of connection and intercourse between ancient and remote peoples. Mythical beliefs are especially referred to as furnishing good evidence of this class, notwithstanding their want of objective value. The conception of weighing in a spiritual balance in the judgment of the dead, which makes its earliest appearance in the Egyptian religion, was traced thence into a series of variants, serving to draw lines of intercourse through the Vedic and Zoroastrian religions, extending from Eastern Buddhism to Western Christendom. The associated doctrine of the Bridge of the Dead, which separates the good, who pass over, from the wicked, who fall into the abyss, appears first in ancient Persian religion, reaching in like manner to the extremities of Asia and Europe. By these mythical beliefs historical ties are practically constituted, connecting the great religions of the world, and serving as lines along which their interdependence is to be followed out. Evidence of the same kind was brought forward in support of the theory, not sufficiently recognised by writers on culture history, of the Asiatic influences under which the præ-Columbian culture of America took shape. In the religion of old Mexico four great scenes in the journey of the soul in the land of the dead are mentioned by early Spanish writers after the conquest, and are depicted in a group in the Aztec picture-writing known as the Vatican Codex. The four scenes are, first, the crossing of the river; second, the fearful passage of the soul between the two mountains which clash together; third, the soul's climbing up the mountain set with sharp obsidian knives; fourth, the dangers of the wind carrying such knives on its blast. The Mexican pictures of these four scenes were compared with more or less closely corresponding pictures representing scenes from the Buddhist hells or purgatories as depicted on Japanese temple scrolls. Here, first, the river of death is shown, where the souls wade across; second, the souls have to pass between two huge iron mountains, which are pushed together by two demons; third, the guilty souls climb the mountain of knives, whose blades cut their hands and feet; fourth, fierce blasts of wind drive against their lacerated forms, the blades of knives flying through the air. It was argued that the appearance of analogues so close and complex of Buddhist ideas in Mexico constituted a correspondence of so high an order as to preclude any explanation except direct transmission from one religion to another. The writer, referring also to Humboldt's argument from the calendars and mythic catastrophes in Mexico and Asia, and to the correspondence in Bronze Age work and in games in both regions, expressed the opinion that on these cumulative proofs anthropologists might well feel justified in treating the nations of America as having reached their level of culture under Asiatic influence.

5. *On Complexional Differences between Natives of Ireland with Indigenous and Exotic Surnames respectively.* *By* JOHN BEDDOE, *M.D., LL.D., F.R.S.*

Taking his data chiefly from the military reports, the author shows that while the former class of Irishmen are largely characterised by the prevalence of light eyes and dark hair, in the latter dark hair is much less frequent. He suggests that a simple mixture of Englishmen, Scotchmen, &c., with the natives should have also decidedly increased the proportion of dark eyes, which has not been the case to any considerable extent; and that the influence of climate, which, if operative at all, should tell in favour of the blonde complexion, may have had some effect upon an unstable cross-breed.

Eyes . .	Light						Dark					
Hair . .	Red	Fair	Brown	Dark	Black	Totl	Red	Fair	Brown	Dark	Black	Totl.
Indigenous names .	3·5	20·6	26·4	19·3	4·5	74·3	1·3	2·9	7·9	10·2	3·1	25·4
Exotic names .	2·4	22·9	29·1	16·2	2·8	73·4	1·4	3·4	10·2	8·7	2·7	26·4

FRIDAY, AUGUST 10.

The following Reports and Papers were read:—

1. *The Report of the Committee on Prehistoric and Ancient Remains in Glamorganshire.*—See Reports, p. 418.

2. *The Report of the Committee on the Exploration of Elbolton Cave.* See Reports, p. 270.

3. *The Report of the Committee on the Explorations at Oldbury Hill.*

4. *On the Evolution of Stone Implements. By* H. STOPES.

The author defined an 'Implement' to be any stone used to facilitate man's actions, not necessarily made, but used; use being determined by wear. By 'Evolution' he meant a series of improvements in flint implements, the result of mental processes and widening experience, though points are reached in all developments, beyond which advance on the same lines stops.

The earliest tools were any chance natural stones used for breaking, bruising, or hammering. Traces of use are not perceived on these unless they were frequently used, when they became worn or polished. The next step was the selection of stones suitable for given purposes, and convenient to be held in the hand. The only signs these show of being implements are also marks of wear. The author showed many such specimens, and referred to the collection of Mr. Harrison, of Ightham. Natural stones were next gradually trimmed for use by a few strokes. These also were illustrated by a series of what the author termed 'transitional' forms, as they are intermediate between the *selected and used*, and the *worked and used*, or Palæolithic implements. The transitional stones are frequently large and rough, generally left-handed, and with thick patination. The terms Palæolithic and Neolithic have become indefinite. Many of the Palæoliths are evidently meant for handles, and some of them are of finer work than the Neoliths. Specimens were shown from many localities, but chiefly from the upper-level gravels of Kent, from 80 feet to 300 feet above the O.D., including anvils, hammers, anchors, net-weights, single- and double-pointed drills or borers, gyrators, axes, spokeshaves, fabricators and arrow-heads; and their parallels were shown from each period. These are the types of many of the steel tools of to-day. A set of sharp-pointed axes having a spiral twist were shown to be developed into the peculiar gyrators of the rock-shelter men, found also amongst the gravels of Swanscomb. Specially instructive are the natural but used stones. Fully half of these show no bulb of percussion. These invaluable records are fast disappearing from free use for concrete and road metal. The importance of preserving worked stones for the use of future students, and the value to the critic of being able to compare a large series together, in order to form just conclusions, were pointed out.

5. *A Joint Discussion with* Section C *on the Plateau Flint Implements of North Kent was held, for which see p.* 651.

SATURDAY, AUGUST 11.

The following Reports and Papers were read:—

1. *The Report of the Committee on the Mental and Physical Condition of Children.*—See Reports, p. 434.

2. *On a New System of Hieroglyphics and a Præ-Phœnician Script from Crete and the Peloponnese. By* ARTHUR J. EVANS, *M.A.*

The author said that the Mycenæan civilisation was in many respects the equal contemporary of those of Egypt and Babylonia, and they might well ask themselves, Was this civilisation wholly dumb? Homer, at least, contained a hint that some form of written symbols was in use.

During a journey to Greece in the preceding year Mr. Evans had obtained a clue to the existence of a peculiar kind of seal-stones—the chief find-spot of which seemed to be Crete—presenting symbols of a hieroglyphic nature. This spring he had been able to follow up his inquiries by the exploration of the ancient sites of Central and Eastern Crete, and the result of his researches had been to bring to light a series of stones presenting pictographic symbols of the same nature, so that he was now able to put together over seventy symbols belonging to an independent hieroglyphic system. More than this, he had discovered, partly on stones of similar form, partly engraved on prehistoric vases and other materials, a series of linear characters, a certain proportion of which seemed to grow out of the pictorial forms. Both these systems of writing were represented as the diagrams exhibited. It would be seen that, as in the case of the Egyptian and Hittite symbols, the Cretan hieroglyphs fell into certain distinct classes, such as parts of the human body, arms and implements, animal and vegetable forms, objects relating to maritime life, astronomical and geometrical symbols. Some of them, such as the two crossed arms with expanded palms, belonged to that interesting class of pictographs which is rooted in primitive gesture language. The symbols occurred in groups, and there were traces of a *boustrophedon* arrangement in the several lines. The comparisons instituted showed some interesting affinities to Hittite forms. Among the tools represented, Mr. Evans was able to recognise the 'template' or 'templet' of a decorative artist, and, with the assistance of a model of this symbol taken in connection with a design supplied by a Mycenæan gem found in Crete, he was able to reconstruct a Mycenæan painted ceiling analogous to those of Orchomenos and the eighteenth-dynasty Egyptian tombs of Thebes (*circa* 1600 B.C.).

The linear and more alphabetic series of symbols was shown to fit on to certain signs engraved on the walls of what was apparently a Mycenæan palace at Knôsos, and again to two groups of signs on vase-handles from Mycenæ. It was thus possible to reconstruct a Mycenæan script of some twenty-four characters, each probably having a syllabic value. It further appeared that a large proportion of these were practically identical with the syllabic signs that survived among the Greeks of Cyprus to a comparatively late date. The Cypriote system threw a light on the phonetic value of the Mycenæan.

Resuming the results arrived at, Mr. Evans said that they had now before them two systems of primitive script—one pictographic, the other linear—both, as was shown by the collateral archæological evidence, belonging to the second millennium before our era, and to the days before the Phœnician alphabet had been introduced among the Greeks. Some pictorial forms, however, of the one series clearly appeared in a linear form in the other; the double axe, for instance, being seen in two stages of linearisation—the simpler form identical with the Cypriote character. On the whole, the pictographic or hieroglyphic series seemed more peculiarly indigenous to Crete, and the linear forms to be Mycenæan in the widest sense. The Eteocretans, or indigenous stock of the island, who preserved their language and nationality in the east of the island to the borders of the historic period, certainly used these hieroglyphs. Mr. Evans gave reasons, based on his recent archæological discoveries in Eastern Crete, for believing—what had long been suspected on historic and linguistic grounds—that the Philistines who, according to unanimous Hebrew traditions, came from the Mediterranean islands, and who are often actually called *Krethi* in the Bible, represented in fact this old indigenous Cretan stock; and that they had here the relics and the writing of 'the Philistines at home.' On Egyptian monuments a people, who came from 'the islands of the sea,' are seen bearing tributary vases of forms, some of which recur on a whole series of engraved gems seen or collected by Mr. Evans in Eastern and Central Crete. Their dress, their peaked shoes, their long hair falling under their arms, all recurred on Cretan designs, representing the inhabitants of the island in Mycenæan times.

3. *Exhibition of Prehistoric Objects collected during a Journey and Explorations in Central and Eastern Crete. By* ARTHUR J. EVANS, *M.A.*

4. *The Heredity of Acquired Characters.*
By Professor A. MACALISTER, *M.D., F.R.S.*

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5. *Notes on Skin, Hair, and Pigment.*
By Professor ARTHUR THOMSON, *M.A.*

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6. *On the Anthropological Significance of Ticklishness.*
By LOUIS ROBINSON, *M.D.*

The ticklishness which is so marked in children, and which is associated with laughter, appears to be different from the ticklishness of the surface of the skin.

Its universal distribution indicates that it was at one time of importance, although at present it appears to fill no place in the animal economy.

It is found that in young apes, puppies, and other like animals, the most ticklish regions correspond to the most vulnerable spots in a fight. In the mock fights of immaturity, skill in defending these spots is attained.

In children, and in anthropoid apes which fight with their canine teeth, the most ticklish regions are practically identical. Young orangs and chimpanzees grin, and behave otherwise much like children when tickled.

It seems probable, therefore, that in the ticklishness of children we have a vestige of a state of racial development when the canine teeth were habitually used by our ancestors in war for mates or food.

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7. *On the Bow as a Musical Instrument.* *By* H. BALFOUR, *M.A.*

The bow has been for a long while commonly accepted as the prototype of a large series of stringed musical instruments. Witness the Greek legend which attributed the first appreciation of the musical potentialities of a tense string to Apollo, who observed them in the twang of the bowstring. In India legend refers the invention of stringed instruments to Siva, who used a bow for musical purposes. In Japan the origin of the six-stringed koto is, in the legend of Amaterasu, traced to an extemporised instrument composed of six bows lashed together. So, too, modern writers have for the most part regarded the bow as a parent form of many of the instruments even of the highest types. Stages in the probable phylogenetic development of stringed instruments may be studied in the *survivals* of primitive forms still existing in various countries. Simplest of all is the monochord of the Damaras (Herero), extemporised from the ordinary shooting bow of the country by the addition of a string bracing the bowstring to the bow, and thus tightening it and dividing it into two parts, whose notes are elicited by tapping upon the string with a small stick. To increase the resonance the bow is held to the mouth of the performer. Stage 2 is represented in many parts of Africa by musical bows, still simple bows, very slightly modified for musical purposes only. These are either held in the teeth or to the mouth, or rested upon resonant bodies (gourds, &c.) to increase resonance. Stage 3 is that in which a resonator is *attached* to the bow, usually a gourd, as in the Zulu 'gubo.' Musical bows in these three stages occur from the Niger down the west of Africa to the Cape, and along the more easterly regions as far north as the Dohr or Bongo tribes. This distribution is nearly continuous. In Asia we meet at the present day with musical bows in forms corresponding with stage 2, as in the Pināka of North India, a lightly made bow strung with fine string. Also the musical bow of the Bhuiyars (aboriginal) of Mirzapur, though this is an aberrant form. It seems likely that a musical bow almost identical with the bow and gourd resonator of South Africa exists in India, this observation being partly based upon a small figure of a man with such a bow in the Pitt-Rivers collection, and partly upon a study of forms which seem to have passed through such a stage. In the Malay regions we find musical bows used with or without resonators in the 'busoi' of Borneo, and in a simple form in

Timor. Eastwards a variety occurs in the 'pangolo' of New Britain, a bow with two strings, one of which is braced to the bow with a string, as in South African examples. In the Solomon Islands miniature bows are played upon with the fingers; at least three varieties are known there, one of which has two strings ('kalove' of Florida Island). In the Marquesas group a musical bow exists; and in the Sandwich Islands an instrument is found which, though it can hardly be called a 'bow,' is evidently closely allied to the two-stringed 'kalove' of Florida Island. In the New World a pretty wide range is seen for the musical bow, but as it is here evidently of African origin, and owes its transmission to the immigration of African labour, the instrument in this region calls for no special remark.

In Africa one may still trace stages in the development of the primitive forms of harps from the musical bow, while the more elaborate harps of the ancient Egyptians and Greeks show unmistakable signs of this original derivation, as does the modern harp of Burma, and that of the Ossetes of the Caucasus, as also several harp-like forms of mediæval times in Western Europe. These all agree in the absence of a supporting front pillar, and the many obvious inconveniences of these forms justify one in saying that these instruments would never have come into existence except as a gradual development from primitive bow-like forms, the awkwardness of whose structure persisted through a somewhat blind adherence to traditional form. In India there is evidence that the 'vina' owes its origin to the bow, there still surviving various intermediate types which can reasonably be regarded as survivals of various stages in the phylogeny of the group.

8. *The Relations between Body and Mind, as expressed in Early Languages, Customs, and Myths.* *By* Rev. G. HARTWELL JONES, *M.A.*

The conditions in which early races lived precluded the possibility of arriving at anything like anatomy or psychology. Yet some crude notions appear in ancient literatures, customs, and myths, and these become more intelligible when viewed in the light of similar superstitions which have prevailed at all times among unprogressive tribes of savages. Naturally, the study of the physical frame and mental constitution received but little attention before the rise of science in the East and Asia Minor.

That the Indo-European *Urvolk* must have had some knowledge of (i.) *the body* is proved by their common inheritance of descriptive *words* for parts of the human frame. Even where the roots of vocables relating to the body are not akin, there is a resemblance in the *conceptions* prevalent in widely distant parts of Europe, and, indeed, of the globe. Among their common possessions are (1) *words*, some describing the creation of the body, others the shape, others the substance. Again, (2) the similarity of the *conceptions* is noteworthy. When analysed, these exhibit a growth of meaning, transition of thought, and gradual gain in distinctness of idea. At first, however, there is constant confusion. Thus the bodily sense is confused with its organ, and a connection was supposed to exist between defects of the body and mental weakness. The habit also of employing one member to represent the whole is frequently found in early stages of language, and particularly in poetry. And if the ideas concerning the body and its parts were indistinct, as was to be expected in the earlier stages of human development, still more vague was the knowledge of (ii.) *the mind* and its phenomena. Especially common among primitive and backward races is the notion that life, mind, and soul are air, vapour, or shade; for example, in Sanskrit, Greek, Latin, and Teutonic languages. Their general idea, too, of the mental faculties was hazy. Even as late as Homer's age the body was regarded as the source of all actions, but by the poet's time knowledge had progressed far enough to discriminate the intellectual and emotional faculties, the power of reflection, memory, and imagination. In this connection several interesting points arise: (*a*) in the growth of language and thought the physical and concrete precede the psychical and abstract; for instance, in Greek, Latin, Persian, Sanskrit, and Chinese. (*β*) There was until a very late period still some confusion between the functions of the different parts of the body, or between the functions of the blood in relation to those of body and mind. Equally loose are the notions respecting (iii.) bodily and mental *disease*. At first the diseased were put to death, and when the healing art originated, diseases were attributed to divine or demoniacal agency. Such was the case even with the Assyrians, Babylonians, and Greeks. This being the case, supernatural remedies were sought, and although by Homer's day human methods were employed, yet traces of the Divine influence are distinctly discernible. This is seen in the propitiation of evil spirits, such as Nosos, Febris, Apollo, Artemis; in the superstitious reverence with which epilepsy and madness were regarded, together with many other superstitions of which glimpses appear as late as Plato. Especially instructive is the worship of Æsculapius, the patron of medicine, whose history, stripped of the legendary lore that has gathered around him, reveals an historical personage. His traditional descent from the Sun-God, his initiation by the Thessalian Centaur, the combination of incantations and prayers, with human aids, like embrocations, salves, potions, and the knife, the peculiar custom of *κατακοιμᾶσθαι*, and the important part played by the serpent and the cock in his worship, exhibit a strange mixture of the natural and supernatural, and well illustrate the early evolution of the art of medicine.

An examination of the growth of knowledge of the body and mind, and their treatment, therefore affords further proof that (1) the primitive condition of the pioneers of civilisation was no higher than that of savages; (2) the parallels presented by words and ideas in countries widely separated from one another cannot be satisfactorily explained by coincidence; (3) the civilisation of Western Europe, viewed as a whole, began in contact with the East.

9. *On the Alleged Presence of Negritoes in Borneo.*

By H. Ling Roth.

The circumstantial evidence collected by the late Mr. Earl that a people of a negroid character existed in Borneo, and the discovery by M. Hamy of a negrito skull from that island, has led to the established belief that negritoes exist there. The skull in question undoubtedly came from Borneo, and it is undoubtedly a negrito skull; but there is no proof that it originated in Borneo. We know that Andaman Islanders (negritoes) have been kidnapped by Malay and Ilanum pirates and carried to India and other parts, so that for the present, in spite of the strong circumstantial evidence, we must withhold our judgment as to whether negritoes exist in Borneo.

10. *On the Possibility of a Common Language between Man and other Animals.*

By Miss Agnes G. Weld.

The authoress pointed out that the Hebrews, Greeks, and Romans believed that at one time man and animals could understand each other's languages, whilst at the present day an Irish peasant will tell you that the cock, on Easter morning, crows in good Erse the tidings that the Lord is risen. In these old and popular legends most stress is laid on the acquisition of human speech by animals, whereas modern scientific effort is tending in the reverse direction. She believes that, with the exception of the parrot and one or two other birds, the creatures below us in the scale of existence are unable to pronounce the full gamut of sounds we can utter, some making use of vowels alone, others merely of consonants, so that it is far easier for us to speak in their language than for them to talk in ours. Miss Weld proceeded to exemplify this by telling of a daily conversation she used to hold with a wild nightingale, and then narrated the remarkable effect produced by her upon a savage retriever that had set upon a collie. Miss Weld described how, when she had growled out certain deep notes of dog language, an awestruck expression came into the retriever's eyes; and how, instantly letting go his hold of the collie, he answered the deep notes by a whispered growl, backing as he did so into a corner, where he remained, in the most abject terror, not venturing to stir till Miss Weld was out of sight.

11. *On Mythical Pygmy Races.*
By Professor Bertram Windle, *D.Sc., M.D.*

In this communication it was shown that the idea of mythical pygmy peoples, fairies, or elves, was diffused throughout the world; that whilst general features of resemblance were present, there were many points of distinction, and notably with regard to the nature of their supposed dwelling-places, an account of which was given.

An attempt was made to show that no single explanation is adequate to account for these legendary races, but that a number of elements enter into the composition of the myth.

MONDAY, AUGUST 13.

The following Reports and Papers were read :—

1. *Pygmies in Europe.* *By* Professor J. Kollmann, *M.D.*

Near Schaffhausen, in Switzerland, a prehistoric settlement was described by the author which had been used successively in Palæolithic, Neolithic, and Metallic times. Each period was distinctly separated from the other by a differently coloured stratum. The Palæolithic stratum contained a large number of the broken bones of reindeer, also those of horse, ice-fox, bear, and other animals in less number. No human bones were found in it, only worked flakes. It was covered over by a layer of breccia, 80 cm. thick, which contained no traces of man.

Over this came the Neolithic stratum, of an average thickness of 40 cm., which contained potsherds and large quantities of ashes, giving it a grey tinge. The animal remains found in it were those of stag, roe, black bear, ox, &c.; the reindeer had entirely disappeared. The uppermost stratum is a layer of humus 40 to 50 cm. thick. During its formation man had ceased to settle there for any length of time under the shelter of the overhanging rocks. A few implements were found in it, but they were of an inferior kind, so that this layer of the so-called Metallic period calls for no further comment. Not so with the Neolithic stratum, in which were more than twenty human interments, both of adults and children. Eleven of the latter varied in age from the new-born child up to that of seven years, and some of them were buried with particular care. The adult interments consisted of the skeletal remains of (*a*) full-grown European types, and (*b*) small-sized people, which must be considered as pygmies of the Neolithic period of Europe. These two races were found interred side by side under precisely similar conditions; from which it may be concluded that they lived peacefully together, notwithstanding their great racial difference. The remains of four of these pygmies, and probably of a fifth, were found. Their stature, estimated according to Manouvrier's method, from the femur, is as follows:—No. 2, 1,416 mm.; No. 12, 1,355 mm., and No. 14, 1,500 mm., giving an average of 1,424 mm. This may be compared with the average stature of the Veddas of Ceylon, which is 1,576 mm., according to Sarasin, and with the skeleton of an Andaman Islander measured by the author, in which the femur measured 424 mm., the stature of the skeleton being 1,500 mm., while the femora of the Swiss Neolithic pygmies are: No. 2, 369 mm.; No. 12, 355 mm., and No. 14, 393 mm.

There were seven interments of the taller race, of which the femur of No. 5 measured 454 mm., giving a stature of 1,662 mm., which Rollet found to be the average height of adult Frenchmen. The remains of the other individuals of this race could not be satisfactorily measured.

The author stated, on the authority of Professor Virchow, that the bones of the small race are not those of a pathologically degenerated people, but of normal structure. In connection with this find it is important to note that Sergi and Mantia have discovered some living pygmies in Sicily and Sardinia, mostly under 1,506 mm. in height in Sicily. In appearance they look like miniature Europeans. In the author's opinion these small types must be regarded, not as diminutive examples of normal races, but as a distinct species of mankind which occurs in several types dispersed over the globe; and he is led to believe that they have been the precursors of the larger types of man.

2. *On some Stone Implements of Australian Type from Tasmania.*
By E. B. Tylor, *D.C.L.*, *F.R.S.*

The ordinary stone implements used by the Tasmanians were remarkable for their rudeness. They come generally under the definition of substantial flakes, trimmed and edged by chipping on one side only, not ground even at the edge, and grasped in the hand without any kind of handle. The Palæolithic level of these implements, notwithstanding their often recent date, had been pointed out by the writer.[1] In illustration of this comparison, Tasmanian implements were now exhibited side by side with flint implements from the cavern of Le Moustier, in Dordogne. But an important point of exception as to this comparison, mentioned in the paper referred to, demands reconsideration in view of the new evidence now brought forward. In the investigation as to native stone implements conducted about twenty years ago by the Royal Society of Tasmania, some exceptional statements were made as to stone axes or 'tomahawks' being ground to an edge, and fixed in handles, and these were explained as due to the Australian natives who have passed into Tasmania since the European settlement. What was meant by these statements now appears more clearly from three ground implements of distinctly Australian character, well authenticated as brought from Tasmania, and now exhibited by the courtesy of the Municipality of Brighton, to whose museum they belong. The largest has a label showing that it was obtained through Dr. Joseph Milligan, probably from G. A. Robinson, the first protector of the aborigines after the native war; and that it was grasped in the hand for notching trees in climbing. The other two specimens are merely marked 'Tasmanian,' with the initials 'G. A. R.' The coexistence of two such different types as the chipped and ground forms in Tasmania requires, however, further explanation. This may probably be found in the immigration of Australians either after or before the English colonisation, but it would be desirable that anthropologists in Tasmania should make further inquiry into the question on the spot, so as fully to clear up the interesting position of the Tasmanian Stone Age.

3. *On Tasmanian Stone Implements.* *By* H. Ling Roth.

4. *The Troglodytes of the Bruniquel, a Grotto of Ironworks on the Borders of Aveyron.* *By* Dr. Emile Cartailhac.

The collection of which M. Emile Cartailhac showed photographs has been formed by the Viscomte de Lastic. It is the complement of the beautiful series acquired some time ago by the British Museum.

The engravings upon bone and the sculptures representing animals are very remarkable, and throw a bright light on the art of the Reindeer Age. Amongst the most interesting objects are the straight beams of reindeer horn, sculptured at one extremity in the form of a horse as seen from the front, head lowered against the breast, feet joined. There are several pieces of this kind, almost similar. Lartet found similar specimens, but broken and unrecognisable, in the layers of the

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[1] 'On the Tasmanians as Representatives of Palæolithic Man' in *Journ. Anthrop. Inst.*, vol. xxiii. 1893, p. 141.

Dordogne. Others have been described in the rock shelters of the Pyrenees and in Switzerland. M. Cartailhac laid stress on the conclusions which can be deduced from the presence of similar pieces in layers so remote. Of all the sculptured objects of the same epoch this is the only one which to any extent had a look of repetition.

M. Emile Cartailhac then entered into an exposition of the facts which led him to consider that neither the reindeer nor the horse was domesticated or bridled during the Reindeer Age.

5. *A New Statuette of the Reindeer Age representing a Woman, Sculptured in Ivory.* *By* Dr. EMILE CARTAILHAC.

The rock shelters of Brassempouy, on the waste land north of the little village of Orthes, includes one of the richest layers of the Quaternary epoch. The mammoth and its contemporaneous fauna are largely represented; with flints, recalling to mind in some instances the types of Laugerie Haute and of Solutré, lay a certain number of the worked bones and also remarkable pieces of sculpture, some of which have been described in 'Matérieux' and elsewhere; others are still unpublished.

Amongst the latter is a broken ivory statuette, collected by M. Dubalen, Conservateur of the Museum of Mont de Marsan, a portion of which M. Emile Cartailhac has reconstructed. The loss of the upper part of the bust in this specimen is very unfortunate, since, if one may judge by the rest of the body, it was carved with great regard to truth and exactitude. This human representation is the best made one which is known of the reindeer period. It proves once more the value of the artistic sentiment of these distant ages.

These engravings and prehistoric sculptures have frequently been compared to those of the primitive populations of North America and Asia, but the more these works multiply, the more they affirm the incomparable superiority of the troglodytes, our ancestors.

M. Emile Cartailhac exhibited the original specimen.

6. *The End of the Stone Age on the Borders of the Mediterranean Basin.* *By* Dr. EMILE CARTAILHAC.

The author explained the analogies and identities proved to exist at the two extremities of the Mediterranean—in Egypt, at Troy, in Greece, and at Santorin at the one end, and in Spain at the other end.

The civilisation, which corresponds to the end of the Stone Age, appears to have special characters and a remarkable uniformity. It does not only influence the same objects, but especially the manners and customs, as shown by exhumed monuments, houses, small market towns, fortifications, and tombs.

Between the East and the Iberian Peninsula, transition is shown by the numerous discoveries in Italy, France, Algeria, Tunis, and the Islands. The connections of this primitive civilisation with the Stone Age of the rest of Europe are remarkable, and illustrate best the diversity of their origins.

7. *On the Present State of Prehistoric Studies in Belgium.* *By* Count GOBLET D'ALVIELLA.

The author reviewed briefly the various investigations which have been made in Belgium regarding the early history of man in that country, beginning with the exploration of the caves, which have in recent years, as well as in earlier times, yielded such interesting results as to their occupation as far back as the period of the mammoth and the reindeer, and also in Neolithic times. He then proceeded to give an account of Quaternary finds in the plains, consisting of flint implements in all stages of manufacture, both of Palæolithic and Neolithic times. The manufacture of flint implements appeared to have been an important industry, extending all over Belgium.

The sites of Neolithic occupation are situated near streams, on the tops of hills, and promontories of high ground. Villages have been found consisting of symmetrically grouped huts excavated in the soil. They contain no trace of metals, only tools of polished flint and fragments of baked pottery made on the wheel, and with linear ornamentation.

Recent researches have shown the existence of Dolmen monuments, which was till lately denied. The existence of a real Bronze Age in Belgium has also been disputed, but finds of bronze articles in tumuli associated with incineration and burials are becoming more numerous.

The beginning of the Iron Age is undoubtedly represented in Belgium in various burial-grounds and tumuli, which have recently yielded new and fruitful researches.

8. *Observations on the Antiquity of Man in Belgium.*
By Professor MAX LOHEST.

9. *Exploration of British Camps and a Long Barrow near Rushmore.*
By General PITT-RIVERS, *F.R.S.*

10. *On a New Craniometer.* *By* General PITT-RIVERS, *F.R.S.*

11. *On the Long Barrow Skeletons from Rushmore.*
By J. G. GARSON, *M.D.*

12. *Report of the Committee on the Glastonbury Exploration.*
See Reports, p. 431.

13. *On Ancient Bone Skates.* *By* ROBERT MUNRO, *M.D.*

The author commenced by observing that the contradictory opinions enunciated by archæologists in regard to the period when bone skates were used justified this attempt to define their position in early European civilisation with greater precision than had hitherto been done. Bone skates had been found in large numbers in the *Terp*-mounds of Holland, and among the *débris* of the ancient town of Birka, on the island of Björkö, in Lake Mälar. Sporadic examples were to be seen in various museums throughout Northern Europe, said to have been found in grave-mounds, lake-dwellings, canal-diggings, &c. The late Dr. Lindenschmit promulgated the opinion that these objects belonged to the Stone Age, and this opinion had been subsequently adopted by various archæologists. In this paper Dr. Munro has collected and criticised the details of all the hitherto-recorded discoveries, and comes to the conclusion that there is no trustworthy evidence in support of the theory that bone skates were ever used in prehistoric times in Europe. According to the author, they would appear to have been invented by the early Teutonic races who inhabited the shores of the Baltic, and to have been introduced into Britain by the early immigrants, who hailed probably from among the superfluous inhabitants of the *Terpen.* This opinion is supported by their geographical distribution, which embraced Holland, Denmark, the lower portions of Scandinavia, North Germany, and a small district in England extending along its eastern shore, including York, Lincoln, and London.[1]

14. *On the People of Western Ireland and their Mode of Life.*
By Professor A. C. HADDON.

TUESDAY, AUGUST 14.

The following Papers were read:—

1. *On three Neolithic Settlements in North Kent.* *By* MRS. STOPES.

Mrs. Stopes treated the topographical relations of the localities in which she has found the traces of Neolithic settlements in the neighbourhood of Swanscombe. They all face east. Is there any possible meaning in this? The shapes of the tools and flakes are very similar, though there must have been long intervals at least between two of them, as one tribe used the pebbles of the Woolwich and Reading beds, the other fresh chalk flints of a fine quality. Mrs. Stopes also noted the information to be gained regarding the chief settlement from the places in which the different types of worked flints are found. The flakes and chips show where the flint-workers worked; the warlike weapons mark the line of defence, &c.

2. *On the Native Tribes between the Zambezi and Uganda.*
By LIONEL DECLE.

After explaining the origin of the name of Mashona—an English corruption of the nickname of Amashuina (baboons) given by the Matabele to the Makalanga—Mr. Decle gave a sketch of the various tribes found between the Zambezi and Uganda, and criticised the classification of the native races according to their language. He explained how, for instance, some tribes classified as Bantu differed physically from others included under the same name. An account was given of the customs prevailing amongst the people between the Zambezi and Uganda. Mr. Decle showed a living specimen from the country he had visited—a young boy, whom he had brought back with him—and gave his history. The boy, who came from the west shore of Tanganyika, had been sold by his own brother to a coast man for two yards of calico. On the way to the coast he got sore-footed, and was sold to a Wahha chief for three goats. When Mr. Decle was in the Wahha country he was attacked every night, and at last, in order to put a stop to it, he one day caught a chief and threatened to hang him if his goods were not returned. After much talking Mr. Decle agreed to take as a ransom the child and ten goats. The boy, although he refused to return to the Wahha or to his own people, was for a long time afraid that Mr. Decle would eat him up.

3. *On the Lex Barbarorum of the Daghestan.*
By Professor MAXIME KOVALEVSKY.

The author insisted on the necessity of more trustworthy information as to old customs and usages being obtained by travellers, and expressed a hope that English ethnographers in India would search for old collections of sentences pronounced by judges As an instance, he mentioned the existence of such a treatise in the Daghestan. It is preserved in Derbent, on the shores of the Caspian, and is known by the name of the Roustem Code. Olearius, a well-known traveller at the beginning of the seventeenth century, mentions his visit to Roustem, who was a kind of elected judge or arbitrator, called an 'outzmi.' His subjects were Tartars of the Kaitag, who had no writing of their own. The treatise is written in Arabic. It contains many very old customs and usages, and admits the vengeance of blood, which extends from the first to the last relatives inward to all the members of the tribe, called 'Touchoum.' Compositions are paid in rough linen called mabzaldick. Whoever wished to escape the obligations of mutual responsibility was obliged to declare solemnly that all ties were broken between him and the members of his tribe, and a nail was placed in the wall of the mosque in commemoration of it. The treatise of Roustem inflicts a high amercement on those who use it without the permission of the 'outzmi.' 'Who keeps his mouth will not lose his head,' is the common saying placed at the top of each sentence. It shows that the mediators in Daghestan, just like the Brehons of Ireland, kept their knowledge for themselves and their pupils.

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[1] This paper will appear *in extenso* in the *Proceedings of the Society of Antiquaries of Scotland*, 1893–94.

4. *On the Natives of the Hadramout.* *By* J. THEODORE BENT.

After referring to the ancient inhabitants and the archæology of this district, the country from which the ancient world obtained its frankincense and myrrh, Mr. Bent went on to describe the present inhabitants of the country and the extreme difficulties in the way of pursuing anthropological research in it. He divided the inhabitants as follows, into four divisions, and gave an account of each.

Firstly, the Bedouins, an obviously aboriginal race, with a religion of their own and mysticism at variance with the orthodox religion of the land. He considered them to be more like the Gallas in physique; and when proper measurements can be taken, in all probability an affinity will be established between these two races on either side of the Indian Ocean.

Secondly, the Arabs proper, who came from Yemen and conquered the country three centuries ago. He gave a description of their women and their customs and fanaticism, of the men who go to India in search of a livelihood, and of the Sultans of the Al Kaiti family.

Thirdly, the Sayyids, a sort of hierarchical nobility who fan the fanatical tendencies of the race and rule everything, both in religion and law; and to them is due the fact that the Hadramout has continued so long to be shut off from exploration and the rest of the world.

Fourthly, the slave element, which in this country is considerable. Mr. Bent described them as living a very happy life and subject to very few social disabilities.

5. *On the Shells used in the Domestic Economy of the Indonesians.*
By DR. J. D. C. SCHMELTZ, *of Leiden.*

The author submitted a systematic list of no fewer than 154 shells used by the aborigines of Indonesia and Oceana in their domestic economy, and a table showing the geographical distribution of their use for different purposes. The author gave an account of the different modes of using shells. Some are much preferred to others, for a great variety of purposes. Shells are also used in connection with religious ceremonies. He concluded with some observations on the manner of making implements, ornaments, &c., from shells.

6. *On the Pantheon of the Fijians.* *By* BASIL H. THOMSON.

The author described the Fijian Olympus, the mountain of Nakauvadra. The tutelar deities of Fijians are the spirits of their dead ancestors. The growth of this idea may be traced in the development of the complete tribe from a single family, and the process may be tested by an examination of the bond of *tauvu*. Tribes that are *tauvu* (*i.e.*, sprung from the same root) worship the same gods.

The author described the legends of the arrival of the Fijians from the westward and the peopling of Nakauvadra; the story of Turukawa and the scattering of the tribes. These fragments of mythology are of historical value.

The recent discovery of the 'path of the spirits,' the legends that cling to it, showing the influence of physical geography on the mythology of the Fijian bogies and apparitions, were briefly described.

The author described the *Nanga* cults, the earliest example of missionary enterprise in the Pacific; the *arcana* of the Nanga and their meaning.

In conclusion he referred to the recent recrudescence of heathen practices and its political danger.

7. *The Distribution of the Picts in Britain, as indicated by Place-Names.*
By J. GRAY, *B.Sc.*

The *Picti* of North Britain, and the *Pictones* or *Pictavi* of South Gaul, are both mentioned by Roman writers. The evidence of place-names shows that probably the whole intervening country was at an earlier date occupied by the same race. Two roots are employed to determine the relative densities of the Picts in Britain—viz. *Pict* and its variants, and *Al.* The language of the Picts was Basque. The name Pict is derived from a Basque word, *pikatu,* to cut. Aquitania is probably a Goidelized form of Paquitania, or Pakitani, and meant in the Pictish language, the country of the Picts. *Pakat* is deduced as the earliest form of the name Pict. The different phonetic changes which *pakat* can undergo are indicated, and some of these are verified by historical evidence. Place-names in the British Isles involving all forms of the root Pakat have been classified under counties and their densities calculated. Goidelic forms where the initial *p* is dropped have been calculated as percentages of the total. Some of the conclusions arrived at are—that the density of the Picts was greatest in the south and midlands of England and in the east of Scotland, and least on the east coast of England, and in Wales. In Ireland the density was only about one-third that in England. The Goidels, who followed the Picts, spread along the valleys of the Thames and Severn to the Mersey, where a part probably crossed to Meath and spread in two streams to the west coast of Ireland; the other part moved northward through Lancashire, Yorkshire, Northumberland, and advanced into Scotland almost to the Forth. A second incursion entered Scotland by Argyll and spread along the west counties to the extreme north. The pre-Pictish inhabitants were probably Iberians, and prevailed mostly in Ireland, South Wales, Cumberland, and South Scotland. The oldest name of Britain, Albion, is derived from *Al,* the name of an Eastern god worshipped by the Picts, and *Bath,* a decayed form of the name Pict.

8. *On the Ceremonies observed by the Kandyans in Paddy Cultivation.*
By B. P. KEHLPANNALA.

WEDNESDAY, AUGUST 15.

The following Papers and Report were read :—

1. *On the Brain of a Young Fuegian.*
By Professor L. MANOUVRIER.

Professor Manouvrier described the brain of a Fuegian child, and compared several of its characters with those of the ordinary European brain. He pointed out that it is interesting anatomically, physiologically, and psychologically to find that the external morphology of the Fuegian brain is nearly equal in its development to that of the European, though some traces of inferiority exist in the former—as, for example, in the third frontal convolution, or the convolution of Broca. The author insisted on the physiological signification of the morphological development of the brain. He believes that the approximate equality of the Fuegian brain to the average European brain does not raise doubts as to the physiological value of cerebral morphology, but rather on the accuracy of the opinion usually held as to the intellectual inferiority of savage people. This inferiority, as that of the ancient Gauls in comparison to the Romans, may result much more from obvious defects in the external conditions which produce civilisation than from true physiological inferiority conjoined with anatomical inferiority. What makes the physiological value of the morphological development of the brain an unknown quantity is that other anatomical, physiological, or external conditions form with it very variable combinations in which the influence of each factor may be masked or counterbalanced by that of others.

2. *On the Valuation of Proportional Dimensions in the Description of the Brain. By* Professor L. MANOUVRIER.

3. *On the Classificatory System of Relationship. By* Rev. LORIMER FISON.

In this paper the author showed the arrangement of the classificatory system of relationship, and the key to it, by an examination of the descendants of two brothers and their two sisters to the third generation.

The Fijian terms of relationship were taken as an example of the system. These divide the sexes in any one generation into groups of non-marriageable persons and other groups of marriageable persons.

The same relatives and their descendants were traced in an Australian tribe, and it was shown that precisely the same groups appear as the result of the division of a community into two exogamous intermarrying divisions, such as are found in Australia.

The inference deduced by the author was that wherever the classificatory terms appear those divisions of the community exist, or have existed in the past.

4. *On some of the Natives of British New Guinea.*
By H. BELLYSE BAILDON, *M.A.*, *F.R.S.E.*

The materials for this paper were obtained during a visit to British New Guinea in 1891, the incidents of which had been detailed by the author's sister in the Geographical Section. The author acknowledged his indebtedness to Mr. and Mrs. Chalmers for corrections and additional information.

The observations extended over the group of villages at Port Moresby, those in the Elema district about Motu-motu; the dangerous inhabitants of Movi-avi; and, again, further east, the people of Kerepuna and Hula.

The natives of Port Moresby consist of two very distinct tribes—the Motuans and the Koitapuans—located in three villages, the principal of which, Hanuabada (the Big Village), is built on the foreshore of the bay. Of the other two, one is on the mainland and the other on the beautiful island of Elevala. The juxtaposition of these two tribes is an instance of that curious intertribal commensalism or economic co-operation often found in New Guinea.

The *Motuans* (who must not be confused with the inhabitants of *Motu-motu*, a very different people) live chiefly by fishing and the manufacture of pottery, while the Koitapuans live mainly by hunting. Much traffic goes on between these two tribes, who supplement each other's requirements, so that commerce here, as in civilised communities, makes chiefly for peace. The Motu pottery is also made for purposes of trading with the Motu-motuans and other western tribes, with whom the Motuans exchange it for sago.

The people of the Elema country and the fertile land of sago about Motu-motu differ in many respects from the Motuans. They seem to be a wilder, more high-spirited and unruly tribe than the more industrial Motuans, who have been called the 'British' of New Guinea, while the others have been likened to the Irish. Nor is the comparison in the latter case without fitness also; for not only in their excitability and impatience of control, but also in their light-hearted gaiety and wit, the resemblances are not far to seek.

The social arrangements here are different from those at Port Moresby, where the people live *en famille* in their cottages; for in Motu-motu the men congregate in large club-houses or *dubus*, while the women and children live in smaller houses. Even married men live in these clubs, and, although they may visit their families, they must always return to the *dubu* before daybreak, otherwise they commit a serious breach of Papuan etiquette. These *dubus* are curious structures built on platforms 14 to 16 feet from the ground, and shaped like the open mouth of a shark. Under the great projecting upper jaw or gable the men lounge and smoke in the daytime, and have their food brought to them here by the women, who are strictly forbidden to enter the interior, which is *helaga*, sacred, or *tapu* to the men. In each village there are several *dubus*, occupied by different clans or families. At a certain age the boys of the clan are taken into the *dubu* to undergo initiation, have their heads shaved, and remain in seclusion till their hair is fully grown.

The remainder of the paper dealt in a similar way with inhabitants of Movi-avi and Kerepuna.

5. *On the Tobas of Gran Chaco, South America.* *By* J. GRAHAM KERR.

The author gave a short account of the manners and customs of the Natokoi or Tobas of the Gran Chaco. This region is inhabited by very numerous nations of American Indians, differing markedly in language, customs, and in minor physical characters. The Tobas are exclusively nomadic in their habits, living entirely on the products of the chase. They usually go about in small hunting parties, larger tribal encampments being only formed occasionally, *e.g.*, at particular seasons. In regard to their mental characters, it was pointed out that they appeared to believe only in the existence of numerous minor evil spirits, who were the causes of disease, accidents, defeats in battle, and other misfortunes; and that their arithmetical powers were very limited, the limit of counting being usually about five.

6. *On the Maya Indians of Chichén Itzá, Yucatan.*
By ALFRED P. MAUDSLAY.

In this paper the author gave an account of some excavations of a burial-mound in the Vera Paz of Guatemala, and the discovery of little jars containing the bones of the little fingers probably deposited by mourners.

The earliest notices of the great Maya ruins at Chichén Itzá, in Yucatan, were discussed, and extracts given from a document lately found by Dr. Marimon in Seville, describing the ceremonies still performed by the Mayas at the great Cenote at Chichén at the time of the Spanish conquest, although the town was already abandoned and the buildings in ruins.

A description was given of the great tennis-court, and a model of it exhibited. The paper concluded by calling attention to some photographs of a hitherto unknown Maya monument at Ixkum, in which the supporters of the Maya figures are captives bound with cords, who are altogether unlike the Mayas in appearance, and probably belong to another race.

7. *On the Loochooan Language.* *By* Professor BASIL HALL CHAMBERLAIN.

Hitherto only two languages have been generally recognised as spoken in the Japanese Empire—viz. Japanese proper, and Aino or Ainu, the language of the hairy aborigines of the north. Professor Chamberlain's paper contains a preliminary sketch of his analysis of a third language—Loochooan—known hitherto, or one might better say suspected, only from a short and exceedingly imperfect vocabulary by the late Lieutenant Clifford, R.N., appended to Captain Basil Hall's

'Voyage of Discovery to the Great Loochoo Island,' published in the year 1818. Mr. Chamberlain has now ascertained that Loochooan stands to Japanese in about the same relation that Spanish does to French. The importance of this discovery will be best appreciated when it is remembered that the Japanese language had hitherto stood in a position of complete isolation, without kindred of any sort. With this new key it will be possible to solve many difficult questions of Japanese philology, and in the paper the author discusses the formation of the negative conjugation of Japanese verbs from this new point of view. Mr. Chamberlain also establishes the fact that Japanese, as we now have it, is the language of the invaders of the Archipelago, not that of the previous inhabitants, by whom the invaders might be supposed to have been absorbed.

8. *Report of the Committee on the North-western Tribes of Canada.*
See Reports, p. 453.

9. *On the Significance of Objects with Holes.*
By Miss A. W. BUCKLAND.

This paper treats of what appears to be a world-wide superstition, belonging to all races and to all time, in which holes are credited with healing and protective powers.

The superstition exists among us at present in the shape of lucky money and lucky stones, but can be traced back to Neolithic times, in the great holed stones and dolmens which are found in Great Britain and Ireland as well as in many countries of Europe, in North Africa, India, Syria, Circassia, and also in America. The chief of British holed stones, the Men-an-tol, is still known locally as the Crick-stone, and through it people creep for the cure of rheumatism.

In Siberia wooden figures bored with holes are carried about as a cure for various diseases, according to the part in which the hole is bored; and figures of great age have been found in Peru and among the Eskimo, which seem from the holes in them to have been intended for the same purpose. Engraved shells also similarly bored have been found in ancient Chaldea and in the American mounds.

The same superstition appears to be traceable in the trephined skulls of Neolithic times found in many countries, and from which amulets have been cut, probably for the cure of epilepsy, the disease for which the operation was undoubtedly undertaken, since it was thus employed up to quite recent times; and the bones of the human skull were always recommended, either grated as a potion, or worn as an amulet, for the cure of epileptic disease.

Miss Buckland believes the healing property thus attached to holes to be of necromantic origin. She regards the hole as the symbol of the underworld, the abode of the Creator in some cosmogonies, and always of the spirits of dead ancestors. Hence they are summoned by the medicine-men to assist them in their healing ceremonies and magic incantations; and thus the hole, through which they are drawn by sorcery, became to the savage the source of healing, and in this form, modified by time, it has descended to us.

The underworld also was the reputed source of wealth; hence the symbolical hole in money caused it to be regarded as lucky money, and this probably explains the use of ring money among the ancients. These symbolical holes are also found in ceremonial weapons in West Africa and in the South Sea Islands, as they were also probably in Ancient Egypt and other countries; the idea suggested being that the bearer of the weapon assumed the power of sending offenders to Hades. Holes exist also in magic wands and in staves, especially in the South Sea Islands, where the holes certainly represent deceased ancestors.

The magic wands and the South Sea staves or idols resemble so strongly the holed implements of reindeer horn found in caves of Palæolithic times, that Miss Buckland believes these staves also to have been used by the medicine-men of that remote period as symbols of the world of spirits over which they assumed control, and that thus we can trace the superstitions connected with holes to the earliest of the human race.

SECTION I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION—Professor E. A. SCHÄFER, F.R.S.

THURSDAY, AUGUST 9.

[The President's Address was delivered on Friday, August 10.—See p. 795.]

THE following Papers were read:—

1. *The Response of Animals to Changes of Temperature.*
By M. S. PEMBREY, *M.A., M.B.*

The simplest method of investigating the response of animals to changes of temperature is to determine the amounts of carbonic acid which they discharge. The carbonic acid is a measure, it may be not an exact one, of the heat produced. From this point of view a series of experiments have been made upon the power which warm-blooded animals possess of varying their production and loss of heat in such a way that their mean temperature is constant.

A mouse is a very suitable animal for such experiments, because on account of its large cutaneous surface compared with its small bulk the reaction to a change of temperature is very rapid. Within two minutes of a fall in external temperature from 30° to 18° the mouse increases its output of carbonic acid by 74 per cent.; within one minute of a change from 33°·25 to 17°·5 the increase is 60 per cent. The response to a rise in temperature is not so rapid: within two minutes of a rise from 18° to 34°·5 the decrease in carbonic acid is 18 per cent.; within one minute of a change from 17° to 32° the decrease is 5 per cent. With cold surroundings the mouse is very active, whereas with a warm temperature it becomes quiet and goes to sleep. The relationship between muscular activity and the production of heat is well shown.[1]

Experiments were next made upon the developing chick. It is a warm-blooded animal, but during its development it was probable that it passed through a stage in which it would have responded to changes of temperature in a similar way to that seen in cold-blooded animals; that in cold surroundings it would have produced less carbonic acid, but that with a rise in temperature it would have increased its output of carbonic acid. The experiments show that during the greater part of the period of incubation the developing chick responds to changes of temperature in a similar manner to that of a cold-blooded animal; that towards the end of incubation, about the 20th or 21st day, there is an apparently neutral stage in which no marked response is seen; that this neutral condition is succeeded, when the chick is hatched, by a warm-blooded stage. The intermediate stage may be the resultant of two opposite tendencies—on the one hand the cold-blooded condition, on the other the imperfectly developed power of regulating the production of heat. When the developing chick is exposed to shock by the prolonged action of cold, this neutral condition may be replaced by a return to the cold-blooded stage.

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[1] 'On the Reaction-time of Mammals to Changes in the Temperature of their Surroundings,' *Journal of Physiology*, xv. 1893, p. 401.

The reaction of the recently-hatched chick is rapid; a fall of 20° in temperature will within fifteen minutes raise the carbonic acid to double its previous amount.

It would appear that this power of regulation depends upon the integrity and full development of the nervous control of muscular action. The chick directly it is hatched possesses great control over its muscles; it is able to run about, feed itself, and perform other complicated movements. At the same time it is able to regulate its production of heat.

It was probable that animals born blind and in a very helpless condition would not possess this power of regulation; that in their case a fall in external temperature would be accompanied by a decrease in carbonic acid, and that with a rise of temperature the output of carbonic acid would be increased. This has been proved to be true in the case of the pigeon. A young pigeon was examined, when it was one day old, and it was found that a fall of 14° in external temperature caused the carbonic acid to diminish to one-third its former value within thirty minutes of the change in temperature. When two days old a similar change of temperature produced almost as great a fall in the output of carbonic acid; raising the temperature to its former level did not cause the carbonic acid to increase with the same rapidity with which it had fallen.

Thus a young pigeon resembles to a certain extent a cold-blooded animal. There is, however, one great difference. The young pigeon responds very rapidly, the frog responds extremely slowly.

To study still further the influence of the nervo-muscular system upon the regulation of temperature by the production of heat, experiments have been made upon mice after section of the spinal cord and during anæsthesia. Both these procedures tend to make the mouse respond in a somewhat similar way to that observed in the cold-blooded animal.

The writer has to thank Messrs. Gordon and Warren for much assistance in some of the experiments.

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2. *On some Experiments to determine the Time-relations of the Voluntary Tetanus in Man.*[1] *By* DAVID FRASER HARRIS, *B.Sc. Lond., M.B.*

1. In a large number of experiments the following apparatus was used:—

A metallic case, made air-tight at each end, was fitted over the forearm from below the elbow to near the wrist. This instrument, practically an air-plethysmograph (for it could register the pulse-beats), had a circular aperture cut in the upper surface, and over this space was fastened a membrane of gold-beater's skin, to which was fastened a disc of platinum. There was no tension exerted on the membrane, which the slightest increase of pressure caused to move, but which, on the cessation of the agitation, came immediately to rest.

Touching the platinum disc was a fine metallic point—the end of a screw supported by an upright soldered to the metallic case. A wire was led to a battery, thence the current traversed an electro-magnetic writer (or 'signal'), and the circuit was completed to the screw-point. The vibrations of the muscles of the forearm thrown into voluntary tetanus (*viâ* the air under the membrane) agitated the membrane, and so made and broke the current, these interruptions in turn synchronously affecting the writing style of the electro-magnet, which traced on a revolving drum a myogram of 'incomplete' tetanus. The rhythm of this as computed from nine different parts of a tracing varied thus: 10, 12, 23·3, 10, 10, 20, 20, 20, 26·6 vibrations per second, or on an average 16·8. The average of a very large number of computations was 13·3.

2. The method employed by Schäfer[2] gave exactly similar results—viz. an average of 10, 8 to 13 being the minimum and maximum rates respectively.

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[1] The paper is published in the *Journal of Physiology*, October 1894.

[2] *Journal of Physiology*, vol. vii.

3. This method was modified as follows:—

A steel spring, strongly clamped at one end, was arranged so that its free end could be bent back to touch a hinged upright connected with a tambour; the recording tambour was in connection as in method 2. By pulling on the spring by the index-finger (the corresponding thumb being at the fixed point of resistance) the vibratory movements of tetanic muscles are communicated through the spring to the air, and so to the recording tambour. The graphic representation of this is very similar to that in 2.

The figures in a typical set of tracings were 9, 6·6, 10, 11·3, 14, 17, 13, 11·7, 18. The average of a large number of experiments was 12·5 vibrations per second.

4. In this, the apparatus was as in 3, except that the myogram was taken on a rotating cylinder, which also oscillated transversely seventeen times per second. The tracing was in places identical with that obtained when one combines two wave-systems whose periods are as 1 : 2; in other places there was a perfectly simple wave-form.

It is contrary to all we know to suppose that the tetanus had twice the rate of the cylinder—viz. 34; the contrary must be true.

If, then, the tetanus had at times a rhythm of 8·5 per second, and at times rose to 17, the mean is 12·75.

5. By a method employing a carbon resistance pile (upon which the muscle was pressed) in the primary circuit of the inductorium, a capillary electrometer in the secondary, and viewing the electrometer through a stroboscopic card, a rate of 12 per second was estimated.

6. By experiments with the microphone, on which the muscle was laid, the rest of the connections being as in 5, the rate was fixed at 12–15.

7. By the microphone laid over the contracting biceps, and a frog's gastrocnemius stimulated by secondary shocks (the microphone being in the primary circuit of inductorium), a rate of 8–15 was estimated, or an average of 11·5 vibrations per second.

The average of these and very many other experiments is 12·5 per second.

3. *On Mirror Writing.* *By* Professor F. J. Allen.

4. *On a Model of the Cochlea.* *By* John G. M'Kendrick, *M.D., F.R.S., Professor of Physiology in the University of Glasgow.*

Professor M'Kendrick exhibited a working moded intended to illustrate the mechanism of the cochlea, devised by himself, with the aid of valuable suggestions by Professor Crum Brown. It consisted of a water-tight glass tank divided into two compartments by a horizontal glass diaphragm. At the end of each compartment a round hole was cut and covered with an india-rubber membrane. The upper hole represented the *fenestra ovalis*, and the lower the *fenestra rotunda*. The horizontal glass plate had two holes cut, each of which was supplied with an india-rubber membrane, and on each membrane there was a steel watch-spring tuned to vibrate at a certain rate. The vibrations of the two springs were as 2 : 1. An arrangement was used for imitating the movements of the stapes, consisting of a rod caused to oscillate horizontally by an eccentric wheel. In this way pendular vibrations were transmitted by the *fenestra ovalis*, and it was shown that when the number of pushes made by the base of the stapes corresponded to the period of spring A, spring A began to vibrate; if the number of pushes was increased A ceased to move; and when the pushes reached the period of B, the latter began to move. Finally, by an appropriate harmonic motion, the wave form of two vibrations of 2 : 1 was transmitted to the *fenestra ovalis*, and both springs vibrated when the period of A was reached, thus showing that the apparatus analysed the compound wave-form. The model generally supported the Helmholtz-Hensen theory of the cochlea. Professor M'Kendrick stated that the Royal Society had enabled him to continue the investigation, and that a more refined apparatus was in course of construction.

5. *On some Physiological Applications of the Phonograph. By* JOHN G. M'KENDRICK, *M.D., F.R.S., Professor of Physiology in the University of Glasgow.*

Professor M'Kendrick exhibited one of the newest forms of the phonographs of the Edison-Bell Corporation, and by the aid of a large resonator adapted to it by himself he was able to cause the instrument to speak so loudly as to be distinctly heard throughout the large room in which the Section met. He explained the mechanism of the instrument, and showed how it might be adapted for recording the voices of two persons at one time, and for transmission of speech to a distance, by using along with it a microphone in a telephonic circuit. He also described attempts he had made to register the voice curves by means of a small and light lever running along the grooves and recording on a small smoked cylinder travelling at a slow rate, and he exhibited curves obtained in this way. His method was quite different from that employed by Professor Hermann, of Königsberg. These curves showed long undulations, at periods of about one second, with the speech curves superposed on these. He also explained methods by which the phonograph might be used for recording respiratory and cardiac sounds, and he stated that, whilst he had been as yet unable to record cardiac sounds, he had obtained several respiratory curves, and also the sound of the ticking of a watch. He announced his intention of continuing the investigation with more delicate apparatus.

6. *On Trophic Changes in the Nervous System.*

By JUSTUS GAULE, *Professor of Physiology, University of Zürich.*

The author has been able by experiments upon the inferior cervical ganglion of the sympathetic to bring about changes in different organs, especially in the biceps and psoas muscles. As the result of further research, he is able to follow out the trophic effect from the spot where the operation is performed up to the organ which subsequently undergoes change. The pathway of this trophic effect passes through the spinal cord; the author in previous communications had already pointed this out as the probable pathway, and now this supposition has been confirmed by microscopical examination. It has been found that the path is marked out by changes of a trophic nature in the nervous system, passing from the point of section to the organ which undergoes change. It was necessary in order to remove any doubt to perform the experiment in such a way that the injury caused by the operation could have little or no part in bringing about the changes in the nervous system.

At last it was found that the trophic changes took place throughout the whole length down to the biceps or psoas muscles when a special nerve scarcely visible to the naked eye was cut away with scissors from its ganglion. This nerve joins the ganglion near the spot where one of the accelerator nerves arises. When the operation is performed in this way the injury is so slight that if the section does not involve the right part of the nerve there are practically no after-effects to be observed in the animal. We must therefore attribute to a special trophic influence those changes which can be observed after the section of the nerve has been properly performed. The changes can be classified according to the different parts of the trophic path in which they lie:—

Those of (1) the sympathetic ganglion; (2) the rami communicantes; (3) the
ganglia and posterior roots; (4) the spinal cord; (5) the anterior roots and
(6) the smaller divisions of the nerves in muscle; (7) the nerve-
cle; (8) and lastly those of the muscle itself.

The changes in each of these parts are of so special a nature that it is impossible to give a short general description of them. In general the changes are of such a kind as if the operation caused some substance to be formed or to soak into the ganglion, and then spread along its nervous connections, bringing about changes in the chemical conditions of the cells of the tissues until the cells are more or less completely destroyed. The alteration spreads along the natural pathways only as long as they are intact; every experiment therefore which destroys the connection produces no trophic effect. It appears that a spread of this injurious substance is possible both in the special ganglia and in the grey substance of the spinal cord, for the number of altered cells is far greater in the case of the spinal ganglion than in that of the sympathetic ganglion. In the grey substance of the spinal cord the change is seen to spread, not only from the posterior to the anterior horns, but also in the direction from above downwards. In those places where the change has reached the anterior horns it spreads through the anterior nerve-roots, and thus arrives at the muscles. At least one finds in the fibres of the nerves which supply the biceps muscle characteristic changes throughout the whole course of the nerves down the brachial plexus to the muscle.

7. *On the Development of Kidney. By* John Berry Haycraft, *M.D., Professor of Physiology, University College, Cardiff.*

The epithelium of the kidney tubules is originally derived from that of the ureter and Wolffian duct, as taught by Kölliker. In the rabbit the ureter branches in the kidney blastema into six or eight tubules, ending in peripheral dilatations, the primitive renal vesicles. These vesicles divide again and again as the kidney grows, keeping to the extreme cortex, and their stalks forming the collecting tubules. All the primary branches of the ureter and many of the above-named collecting tubules become evaginated to form the pelvis. From the primary renal vesicles the rest of the tubules grow out as solid and then hollow processes and the Bowman's capsule is moulded on a bend of its own tubule, and is not invaginated by a glomerulus. After birth the primary renal vesicles shrink down to the size of an ordinary tubule, but at birth they may be seen as dilatations of the collecting tube when it reaches the extreme cortex and turns round into the region of the convoluted tubules.

FRIDAY, AUGUST 10.

The President, Professor E. A. Schäfer, F.R.S., delivered the following address:—

Before beginning the subject-matter of my address I had conceived it to be necessary, appearing before you as we do as a new Section, to offer some sort of apology for our presence. But, on looking up the history of the Association, I find that my task is somewhat different. If I have any apology to offer at all it is that the Section of Physiology has ceased to appear for many years.

The British Association was founded at York in 1831; and at the subsequent meeting, which was held in this very city of Oxford, amongst other Sections which were established, was one for Anatomy and Physiology. Now, when we consult the records of this Section we are struck with the fact that Medicine early shows a marked preponderance. Thus, in 1833 a physician, Dr. Haviland, is selected as President for the Section; and the secretaries are Dr. H. J. H. Bond, who was Regius Professor of Physic in the University of Cambridge from 1851 to 1872; and Mr. (afterwards Sir) G. E. Paget, who succeeded Dr. Bond in the Regius Professorship. This preponderance soon came to be recognised in the designation of the Section, for in 1835 we find it entitled Section E, Anatomy and Medicine.

As time went on the interests of medical men became gradually more absorbed in the rapidly growing British Medical Association; and in 1841 the medical title was dropped, and the Section came to be called simply Physiology, which title it retained until 1847. Under that designation the Section has now been revived.

The fact that Physiology as a separate Section in this Association was allowed to lapse for so long a period is not remarkable when we remember that during the first half of this period Physiology as a science was practically non-existent in this country. The teachers of Physiology were, almost without exception, practising physicians and surgeons, and even when a professor was expected to devote his time to the teaching of Physiology he was not expected to devote part of that time to the prosecution of physiological research. During all these years, from 1833 to 1847, we do not find amongst the officers of the Section any actual working physiologists. Most of the officers were distinguished medical men, with an anatomist here and there amongst them. Far be it from me to say that there was no actual work being done in Physiology at this time; for Charles Bell and Marshall Hall were engaged in elucidating the functions of the nervous system; whilst Bowman, Wharton Jones, and others were producing good and permanent work in various other departments of Physiology. Their labours, however, were isolated, and formed but oases in the Sahara of neglect into which the pursuit of Physiology had fallen in this country; and this during a period when it was being pursued with signal success and activity both in Germany and France.

After 1847 a revival of Physiology began to manifest itself even here; and this was followed by the establishment, from time to time, of a sub-section to Section D, which was devoted to Physiology, and had a special President. Whether, however, owing to their subordinate character, or from some other reason, these sub-sections had not usually any great measure of success, and for the last twelve years they have been wholly dropped. During that period Physiology has only twice been represented in the Chair of Section D, and has usually had no secretarial representation. This decadence of Physiology in the British Association during the last eleven or twelve years is the more remarkable because it is obviously not due to any want of outside activity in regard to the subject; for during this period we find an extraordinary revival of interest in physiological research, a revival which in its most active stage dates from about twenty-five years ago, but still some twenty or thirty years later than the corresponding revival in France and Germany. I have taken the trouble to prepare a list of prominent physiological workers who flourished during the thirty years prior to 1870. My list comprises, in all, thirty. Of these, four are English, five French, and twenty-one German or Dutch. Of the four English working physiologists not one is a teacher of Physiology. Of the five French and twenty-one German all are recognised teachers. It was not, in fact, until it came to be understood that teaching and work in Physiology, as in all branches of science, ought in the main, to be successful, to go hand in hand, that the science had any possibility of revival.

Let us glance for a moment at the history of the revival of Physiology in this country as compared with its revival in Germany. In each country the revival may be said to have been largely due to the influence of one teacher. In Germany the teacher was Johannes Müller; in this country, William Sharpey. Both of these remarkable men were pupils of Rudolphi, who was Professor of Anatomy and Physiology in Berlin until 1833. It is stated regarding Rudolphi that 'he was an enemy to subjective speculation in biological science: he looked on the so-called philosophy as mistaken and futile in its application to the phenomena of the animal economy, and based his physiology chiefly, and perhaps rather exclusively, on the study of the animal structure.' The influence of Rudolphi is apparent in both Müller and Sharpey.

Müller was born in 1801, Sharpey in 1802; they were therefore of about the same age. But Müller's scientific and intellectual development was more rapid than that of his contemporary. Thus we find that already in 1826, when he was but twenty-five years old, Müller attained so great a reputation as to be made Professor Extraordinary in the University of Bonn; and before very long he was promoted to the grade of Ordinary Professor there. In 1833, whilst still a young man, he was called to the chair of Anatomy and Physiology at Berlin, which had just become vacant by the death of his master and friend, Rudolphi. Sharpey, on the other hand, occupied himself until 1829 with perfecting both his general and his special anatomical education. It was not until 1830 that he published his first essay in anatomical and physiological research entitled 'On a Peculiar Motion excited in Fluids by the Surfaces of Certain Animals'—observations which were preliminary to the discovery of the existence of cilia in vertebrates. And it was not until 1836 that he was called to the newly instituted professorship of Anatomy and Physiology in University College, London, which he filled for so many years with such signal success. Both of these distinguished men owed, there is no doubt, their success as teachers of Physiology to their early anatomical training. The general anatomical bent of Johannes Müller is evidenced by the fact of his scientific work being turned so much in the direction of Comparative Anatomy and Physiology. And Sharpey, although great, and deservedly great, as a teacher of Physiology, remained to his dying day, above all, an anatomist. Physiologists of this school are rare at the present day; but it is probable that in some respects the progress of Physiology may suffer thereby. Helmholtz began his public career as professor of Anatomy; but it would be unfair to attach too much weight to this particular incident in the case of so many-sided a man as the great Berlin Professor of Physics. Nevertheless, the necessity of a close and careful training in Anatomy for those who are afterwards to work at or to teach Physiology is so important that I do not hesitate to say that the younger physiologists who neglect the study of Anatomy will find that before very long they must abandon the pursuit of many byways of Physiology which might otherwise be followed up with manifest advantage.

The influence of Johannes Müller upon the revival of the pursuit of Scientific Physiology in Germany, and indeed generally, cannot be overestimated. We have only to look at the names and eminence of his pupils in order to recognise the immense influence which his teaching has exerted upon the progress of Physiology ever since his time. Some of these pupils are still amongst us, others have joined the majority. But the pupils of these men, again, are now great names in many departments of our science, and through them we cannot fail to recognise the influence which was exerted by this truly great man.

We may say the same in almost identical words of William Sharpey. The practical pursuit of Physiology in this country has mainly radiated from the centre where Sharpey taught. Michael Foster was his pupil. The physiological investigations of Burdon-Sanderson were assisted and encouraged by him. From Sharpey, therefore, we may trace the rise of the great school of Physiology at Cambridge, and we have only to look at the magnificent laboratory which has been erected here to observe a monument of the influence of the same teacher. And there have emanated either directly from the physiological school established by Sharpey at University College, or indirectly from those at Cambridge and Oxford, many of the most active teachers and workers in Physiology in the kingdom.

In these respects there is much in common between the revival of Physiology in Germany and in this country. In other respects, however, the two cases have been entirely under different conditions. There its revival, in common with that of science generally, has been assisted and stimulated by the active and beneficent co-operation of every German State. Here, also in common with science generally, it has had to make its way against every conceivable obstacle; and almost without assistance, either moral or material, from the Government or from public bodies. But not only has it not met with assistance, there have been actual obstacles placed in the way of teaching and work in Physiology. Some have been unintentional, others intentional. As an instance of the unintentional may be mentioned the practice which has obtained in medical schools and on examining boards—a practice which, I am happy to say, is gradually being discarded—of appointing as teachers and examiners in Physiology men who may have a good general knowledge of the science, yet with whom it is not the business of their lives, and who cannot, therefore, be expected to be as familiar with its details, and as absorbed in its interests, as those who devote their entire time and attention to its pursuit.

The more virulent opposition, in some measure, to science generally, but in the greatest measure to Physiology, appeared almost simultaneously with the active revival of the subject. This opposition, which has come to be known as the Anti-vivisection Movement, but which might equally well be called the Anti-scientific Agitation, has hitherto met with no measure of success, except that it has to a certain extent hampered the full development of the science by diverting to its defence some of the energy which might be devoted to its pursuit. Indeed, the actual results of this unreasoning agitation furnish an illustration of the old-established principle that persecution of a good cause will in the long run tend towards its development and propagation. And in this case the chief results have been the following:—

1. The most immediate effect of the anti-vivisectionist attack was the establishment of the Physiological Society, which in the first instance was only a small gathering of working physiologists, who met to discuss measures of defence in a drawing-room in Queen Anne Street. This society, which had such a small beginning, is now large and important. Its doors are besieged by applicants for admission, although it is a necessity for such admission that the applicant be either a teacher of Physiology or a worker at Physiology, or both. Its numerical strength has grown from ten or fifteen to more than 150; and its numbers are every year increasing. And, besides the work which it has done in this country in promoting the interests of Physiology, and co-operation between English physiologists, it has succeeded in establishing a succession of Triennial International Congresses of Physiology, which are amongst the most successful of such gatherings, and which have been the means of bringing us into communication with the most prominent physiological workers and teachers on the Continent.

2. A second result of the agitation was the passing of the so-called Cruelty to Animals Act. This Act, which was intended to restrict the performance of experiments upon animals, was in no sense called for, since it had been found by a Royal Commission that there was no evidence to show that there had been unnecessary experimentation upon animals, or any desire on the part of physiologists to neglect the use of anæsthetics. On the other hand, it is of inestimable advantage in that it gives the public a definite guarantee that the excesses of which physiologists used to be freely accused are not possible. Such excesses never did actually occur; although, to believe all the publications which have been issued by Anti-vivisection Societies, one would come to the conclusion that a physiologist is a being who spends his whole time in torturing sensitive creatures, careless of the suffering which he may cause, or even of the scientific results which he may obtain. The fanatical supporters of the agitation would have you to believe that we are all neither more nor less than 'fiends;' they cry with Ferdinand that 'hell is empty and all the devils are here.'

I am told there was even a feeling of this sort in this University at the time when it was proposed to establish the Waynflete Professorship of Physiology, and that an agitation was set on foot having for its object, first, the prevention of the establishment of such professorship; and secondly, that being impossible, the prevention of the professor's practising Physiology. The common-sense of the University stifled this agitation, and the more intimate acquaintance with physiologists which has resulted from the establishment of the school has been sufficient, I believe, to smother the little fire which was still left smouldering.

3. A third result of the Anti-vivisection Agitation was the establishment of the Association for the Advancement of Medicine by Research. This immediately followed a unanimous resolution of the International Medical Congress of 1881, affirming the necessity of experiments upon animals. To the ignorant accusation that physiological experiments had been and were of no use or influence in the advancement of medicine, the leaders of the profession unanimously affirmed that it is upon Physiology that Medicine and Surgery are based, and that there can be no real progress in those sciences without a corresponding progress in Experimental Physiology and Pathology. The Association for the Advancement of Medicine by Research has been of the greatest possible value and assistance to Physiology in this country. It has shown physiologists that they have the great

medical profession at their back, and it has acted as an impartial and independent medium of communication between physiologists and the successive Secretaries of State, whose business it has been to administer the Act.

4. A fourth result of the attacks of the anti-vivisectionists has been, I may perhaps be permitted to believe, the re-establishment of this Section of Physiology of the British Association. Those who were present at the meeting of the Association in Nottingham may have remarked that the gutters of that town were strewn with papers which had been forced upon the members of the Association by the anti-vivisectors of the place. This literature, which in a double sense may be termed 'gutter literature,' teemed with flagrant misstatements, and with vicious calumnies, directed against physiologists, and especially called forth, I presume, by the fact that for the first time in the history of the British Association a physiologist was called upon to occupy the presidential chair. We may look upon the establishment of this Section as the reply of the Association to the false witness which was borne against us at Nottingham.

But although a special section for Physiology has been re-established, it may not be advantageous that there should be one at every meeting of the Association. Physiology is above all things a practical science. It requires laboratories and means of demonstration. Physiologists are rarely satisfied with the opportunity of hearing and reading papers, but require that, as much as possible, the actual methods of research employed should be capable of demonstration. By this I am not to be supposed to advocate the demonstration of experiments upon animals, for there are very many subjects in Physiology which can be both worked at and illustrated in a manner involving in no sense whatever the word vivisection. But in order that the methods should be shown, it is important to have the appliances of a laboratory at hand, and the Association frequently meets in towns which are not university towns, and have no laboratories, in which, therefore, it would be difficult or impossible to arrange for demonstrations of the sort that I am alluding to. On this account we may well imitate the practice of the British Medical Association, which establishes a Section of Physiology only when its meetings are held in such a centre as is likely by the appliances which are to be found in that centre to render the Section useful and efficient. Hence, in recommending the establishment of a Physiological Section, it is expressly reserved that the Section shall be held only at such future meetings as may seem to the Council to be desirable.

I will now invite you to consider with me one or two of the more obscure subjects in the range of Physiology, subjects which are, however, creating a great, almost an absorbing, interest at the present moment. The first of these subjects relates to the structure and function of every cell in the body. All are aware that the body of every animal and of every plant is made up of minute corpuscles which are formed of protoplasm, and which contain in every case at least one nucleus. The protoplasm and the nucleus form the living substance of the cell. Other substances may be present, but they are, in a sense, outside the nucleus and protoplasm, not incorporated with their substance. Apart from a few details relating to the structure of the nucleus, this was, until quite lately, practically all that we knew regarding the parts composing either the animal or the vegetable cell. There appears, however, to be yet another something which, although in point of size it is of very insignificant dimensions, yet in point of function may perhaps be looked upon as transcending in importance, in some respects, both the protoplasm and the nucleus. Not many years ago it was noticed by various observers that in certain specialised animal cells the protoplasm showed a tendency to radiate from or converge towards a particular point, and on further investigation it was found that at this point there was a minute particle. This observation, which began, as we have seen, upon specialised cells, was, after a little while, found to hold good for other and yet other cells, until, at the present time, we believe that in every cell of the animal or plant body such a particle exists. Now, it may well be asked, why after all should so great importance be attached to this observation? To this it may be replied that, in the first place, it is of importance, because it shows conclusively that the whole cell is not of a uniform nature, since there is this one point within the cell that exerts a special attraction upon the rest of the cell-substance; and, indeed, on this account the particle has come to be termed the 'attraction particle.' And in the second place, because of the apparent universality of the occurrence of such a particle. And, thirdly, because of the fact that one of the most important phenomena exhibited by the cell hinges upon the behaviour of this particle; for it is found that before a cell or its nucleus divides this minute attraction particle begins by itself dividing, and is, in fact, more commonly met with double than single. Nor is it until the two particles thus produced have evolved, either from themselves or from the substance of the protoplasm or nucleus, a system of communicating fibres, the so-called *achromatic spindle*, that those changes in the nucleus and protoplasm take place which produce the division and multiplication of the cell. This *attraction particle*, which is also called the *central particle* or *centrosome*, has absorbed so great an interest that, short as is its history, many papers have already been devoted mainly to it, the latest of these being an elaborate treatise of some 300 pages by Martin Heidenhain. I shall not here attempt to follow out the details of all these researches, but will be satisfied with putting before you the conclusion which Heidenhain has come to regarding this particle, viz., 'that it is morphologically, physiologically, and chemically a structure *sui generis*; not merely a separate portion of nucleus or of protoplasm, but an organ of the cell with definite functions, and having a definite existence of its own.' Nevertheless, it is almost as minute an object as it is possible to conceive. In a cell which is magnified a thousand diameters the central particle appears merely the size of a pin-point. Yet this almost infinitely small object exerts an extraordinary influence over the whole cell, however large (and the cell may be many thousand times its size), for it initiates and directs those processes which result in the multiplication of the cell, and indirectly, therefore, it is concerned in directing the general growth of the individual, and ultimately the propagation of the species.

A former President of the Association took as the subject of his presidential address what he was pleased to call the 'Next to Nothings.' In considering this central particle, of the actual structure of which, and of its chemical constitution, we know at present hardly anything, we may surely regard it as a striking instance of the supreme importance of the 'next to nothing' in Physiology.

The other subjects to which I desire to draw your especial attention relate to the physiology of certain organs the functions of which have always been extremely obscure, and which, although they differ greatly from one another in almost every point of structure, and presumably also in function, it has been usual to group together under the name of ductless glands. The name 'gland' is given to such organs of the body as take materials from the blood, and convey those materials in an altered or unaltered form, by a tube or duct, to a surface either internal or external. Such material is termed the secretion of the gland, and has for its object either the performing some function which is useful to the organism or the getting rid of material which would be detrimental if retained. In the case of the ductless glands there is no such possibility of pouring out material produced by the gland upon a surface, because these organs do not communicate with any surface by a duct; and whatever material they may furnish must therefore, if it is to reach the body generally, pass into the blood; that is to say, the blood on the one hand must furnish the materials for the secretion of the gland, and on the other hand it must take up those materials after they have been manufactured into something else, and carry them away to other parts of the body. Now, in the case of a certain number of the ductless glands there has not appeared to be any very great obscurity as to their function; for some of them seem very obviously to be devoted to the formation of corpuscles which are found within the blood itself. But with regard to others of these bodies it has not hitherto been possible to find any special material in the blood which they have furnished to it, and our knowledge of them is derived almost entirely from experiments. I will take the case of two of these to illustrate the vast influence which small and almost disregarded organs may exert upon the whole economy. But in the first place I may be permitted to point out what is indeed a self-evident statement, that there is no part of the body which does not exert some influence upon the rest. Every single portion of the body is continually taking materials from the blood, and furnishing to the blood other materials which are formed within it, whether we call that portion which performs such functions a gland or not; and it is quite certain that the removal of any portion of the body would be followed by some permanent alteration in the blood were it not that other similar parts may by increased activity compensate for the alterations which the blood would otherwise undergo from the loss of any one such part. Take the case of a limb. The changes which the blood undergoes in circulating through it affect the body generally through that fluid, for the composition of the blood becomes modified in traversing the limb. And not only is the body affected thus through the medium of the blood, but, by means of the nerves which pass to and from the limbs, the central nervous system is itself affected by the movements and alterations of various kinds which are proceeding in the muscles and other parts, and through the nervous system the whole organism must constantly be influenced from the limb. There is, however, no evidence that the removal of a limb or part of a limb permanently modifies either the condition of the blood or of the nervous system. Nor is such a result to be expected, for in this case there are other parts of the body possessing similar organs and performing similar functions, the increased activity of which may easily compensate for the loss which is sustained through removal of such a part.

But if we deal with an organ which is not multiple, but unique, and completely remove this from the body, it is easy to see that the case may be very different. This organ, like every other organ of the body, is continually taking from the blood some materials and giving up to it certain other materials. Now it is clear that its removal must make a permanent difference in the blood, and, since the whole organism is remarkably sensitive to even slight changes in the composition of the circulating fluid, very marked results may well follow the removal of such organ. And this is in fact found experimentally to be the case.

It has long been known that extensive disease of the thyroid gland, a small reddish organ, weighing about one or two ounces, found at the front of the throat, is followed by extensive alterations in the nutrition of the body generally. The patient becomes swollen from the overloading of the connective tissues with a mucinous exudation; the nervous and muscular systems are seriously affected; the power of generating heat is greatly modified; and the final result is, in the first instance, the production of a condition of semi-idiocy, ultimately followed, if the disease be extensive, by death. Precisely similar results have been found in animals, and in fact in man as well, to follow the complete removal of this body. Yet the weight of this organ is not more than one sixteen-hundredth part of the whole weight of the body; and even this figure does not represent the enormous influence which a relatively small organ can exert upon the general nutrition of the body; for it is found that even if a minute part of the thyroid gland be left whilst the greater part is removed, the symptoms above enumerated do not supervene. Indeed, certain contradictory results which have been got by some observers after removal of the thyroid are explained by the fact that in some individuals there are minute detached particles of thyroid gland lying apart from the main organ; and that after the latter has been removed these detached particles may sufficiently carry on the function of the organ in relation to the blood and the nervous system to prevent the supervention of the deleterious symptoms which usually occur after its removal. Here is, then, a notable instance of the enormous influence exerted by a 'next to nothing' upon the general organism.

Another illustration may be given from these ductless glands. It was noticed in 1849 by a celebrated physician, Dr. Addison, of Guy's Hospital, that certain cases, accompanied by extreme debility, occurring in the human subject were associated with the appearance of peculiar bronzed patches on parts of the skin and mucous membranes; and on *post-mortem* examination of these cases, which always sooner or later have a fatal termination—and indeed sooner rather than later—he found the symptoms in question to be accompanied by disease and destruction of the supra-renal capsules—small bodies which are placed close to the kidneys, but which, so far as we know, have no physiological connection with them. Now, when experiments came to be directed upon these bodies in order to elucidate their functions, and especially to observe whether their injury or removal was accompanied in animals also by symptoms similar to those occurring in man as the result of disease, it was found by Brown-Séquard that when these bodies are totally removed in any animal the removal is speedily followed by a fatal result. These experiments of Brown-Séquard's were made in 1858, and at the time attracted some attention. They were repeated by other experimenters with similar effects. But some of those who removed the supra-renal capsules obtained contrary results, and for many years the matter remained in an undecided condition. It was even supposed that the fatal results which were got by Brown-Séquard might be due to the shock of the operation or to the fact that the removal necessarily involves certain parts of the sympathetic nervous system, and were not necessarily due to the removal of the supra-renals. Recently, however, attention has been again directed to the subject, and the experiment of Brown-Séquard has been repeated by Tizzoni (1889) and by Abelous and Langlois (1891 to 1894) in various animals—viz. frogs, guinea-pigs, rabbits, and dogs. I have myself performed confirmatory experiments in monkeys. The result of all these recent observations is to show that the complete removal of the supra-renal capsules is not compatible with prolonged existence of life; and Abelous and Langlois have shown that it is accompanied by an alteration in the blood, which renders that fluid poisonous to other animals. The contrary results which have been obtained by some investigators are apparently due to the fact that in certain cases there are, as with the thyroid body, small isolated portions of supra-renal substance ('accessory capsules,' as they are sometimes called) which have not been noticed and removed at the time of the operation, and that these small portions of supra-renal substance have served to maintain that proper relation between the blood and the gland which is sufficient to prevent the supervention of the symptoms in question.

Now the weight of both supra-renal capsules taken together is not more than three drachms, and their weight, as compared with that of the whole body, is only as 1 to 6,000 or less. The accessory supra-renal capsules which may be left after the removal of the main bodies probably do not originally weigh more than one-twentieth of the whole structure, and yet this minute proportion of material (a material, so far as we know, unique in the organism) is nevertheless sufficient to maintain the composition of the blood and the nutritive equilibrium of the body, and thus to prevent the necessarily fatal result of complete removal.

Now it has been found in the case of the thyroid gland that patients in which this structure has been so diseased that its function is seriously interfered with, and animals in which it has been removed entirely, may be greatly benefited, if not indeed cured, by the inception, either subcutaneously or with food, of the thyroid glands of animals, or of the juice of such glands. Even where no affection of the thyroid can actually be detected, the exhibition of thyroid juice is frequently beneficial in certain conditions of the system; and it was noticed by Dr. Oliver, of Harrogate, that this is especially the case where there is a too-marked constriction of the blood-vessels, the juice of this body tending in such cases to reduce the extreme tone of the vascular walls, which is the cause of this condition. Encouraged by this result, Dr. Oliver was led to examine the effects of other animal extracts, and among them that of extract of supra-renal capsule. The effect of this was precisely the reverse of that which he had got with the thyroid body, for he obtained evidence tending to show that in certain cases in man extract of supra-renal capsule can produce an *increase* of vascular tone and a diminution in the size of the arteries. Beyond this point, however, Dr. Oliver was unable to proceed by clinical experiment, and he accordingly came to my laboratory with the object of determining the precise physiological effect of the active substance of the capsules. The results which were obtained show that there is present in both alcoholic and watery extracts of the gland a most potent physiological substance which when injected into the body of an animal produces, even in minute doses, a remarkable effect upon certain parts of the nervous system, upon the muscular system, upon the heart, and upon the blood-vessels. If only as much as a grain by weight of supra-renal capsule be extracted with alcohol, and if this alcoholic extract be allowed to dry, and then be redissolved in a little water or salt solution and injected into the blood of a dog, the results which are obtained, considering the minute amount of substance added to the blood, are certainly most extraordinary. The nervous centre which regulates the action of the heart is powerfully affected, so that the heart either beats very slowly and weakly, or the auricles may even for a time stop beating altogether. If, however, these inhibitory influences be cut off by division of the vagi nerves, the effect of the poison upon the heart is of an opposite character. There is great acceleration of the rate of the beat and a great increase of force. This is accompanied by a strongly marked influence upon the blood-vessels, and especially upon the arterioles. The walls of these are chiefly muscular, and the drug exerts so powerful an action upon this muscular tissue as to cause the calibre of the vessels to be almost obliterated. The heart being thus increased in force and accelerated, and the calibre of the vessels almost obliterated, the result is to raise the pressure of the blood within the arterial system to an enormous extent, so that from a blood-pressure which would be sufficient to balance a column of some four inches of mercury the pressure may rise so high as to be equal to a column of mercury of twelve or more inches.

This result is obtained, as we have seen, by a very minute dose. We have to do here with a substance which is as potent, although in a different direction, as strychnia. Whether it is a useful substance formed by the supra-renals from materials furnished by the blood, and subsequently gradually used in the economy for the virtue of its action upon the circulatory system, or whether it is to be regarded as a poison, formed by the tissues during their activity and carried by the blood to the supra-renals, there to be rendered innocuous, we do not as yet certainly know. These are important points which must form the subject of further investigation. But, however this may be, it is clear that in this gland also we again meet with an instance of the physiological importance of what Sir Frederick Bramwell called the 'next to nothing.'

I will give one more instance, taken this time from a gland which is provided with a duct. Until quite recently it might have been thought that there was nothing very obscure regarding the functions of the pancreas. The pancreas is a digestive gland which lies below and behind the stomach: it has a duct which carries its secretion into the beginning of the intestine, and that secretion acts powerfully upon all constituents of the food, digesting starch, meat, and fat. It was not supposed that the pancreas had any other function to perform. Animals can live without this secretion, and to a large extent can continue to digest and absorb their food much as before; for it has been possible to divert the secretion from the intestine and to collect it at the surface of the body; and it is found under these circumstances that, although the food is not quite so readily digested, nevertheless the animal does not materially suffer from the lack of the secretion. It was discovered, however, a few years ago (by v. Mering and Minkowski) that if, instead of merely diverting its secretion, the pancreas is bodily removed, the metabolic processes of the organism, and especially the metabolism of carbohydrates, are entirely deranged, the result being the production of permanent diabetes. But if even a very small part of the gland is left within the body, the carbohydrate metabolism remains unaltered, and there is no diabetes. The small portion of the organ which has been allowed to remain (and which need not even be left in its proper place, but may be transplanted under the skin or elsewhere) is sufficient, by the exchanges which go on between it and the blood generally, to prevent those serious consequences to the composition of the blood and the general constitution of the body which result from the complete removal of this organ. Now, some years ago it was noticed by Kühne and Sheridan Lea that, besides its proper secreting structure composed of tubular alveoli, lined by granule-containing cells, there are highly vascular patches of peculiar epithelium-like cells scattered here and there in the substance of the pancreas, which are wholly unconnected with the ducts and, so far as one can judge, with the secretion of the gland. We do not know anything whatever about the function of these patches, although from their vascularity it is extremely probable that they are not without importance physiologically, and it is tempting to conjecture that it is these cells which are specially concerned in effecting that influence upon the metabolism of carbohydrates which experiment has shown to be peculiar to the pancreas.

The lesson to be drawn from these results is clear. There is no organ of the body, however small, however seemingly unimportant, which we can presume to neglect; for it may be, as with the supra-renal capsules, the thyroid gland, and the pancreas, that the balance of assimilation and nutrition, upon the proper maintenance of which the health of the whole organism immediately depends, hinges upon the integrity of such obscure structures; and it is the maintenance of this balance which constitutes health—its disturbance, disease. Nor, on the other hand, dare we, as the investigation of the attraction-particle has shown, afford to disregard the most minute detail of structure of the body.

> 'All is concenter'd in a life intense,
> Where not a beam, nor air, nor leaf is lost,
> But hath a part of being.'

The following Papers were read:—

1. *On the Absorption of Poisons.* *By* Professor P. HEGER, *Brussels.*

2. *On a New Theory of Hearing.* *By* C. H. HURST, *Ph.D.*

3. *On the Fats of the Liver.* (*A preliminary Communication.*)
By D. NOEL PATON.

It is pointed out that while the liver has been demonstrated to play an important part in the metabolism of carbohydrates and proteids, its possible connection with the metabolism of fats has not been investigated.

In the present series of observations an attempt is made to elucidate—

A. *The Source of Liver Fats.*

I. Are they directly stored from the fat in the food?

- *a.* Do they accumulate in the liver after a meal containing fats?
- *b.* Does the quantity of fats in the liver bear any proportion to the quantity of glycogen?

II. Are they formed from the fats in the adipose tissue of the body?

- *a.* Consideration of phosphorus poisoning.
- *b.* Relative amount of fats in liver and adipose tissue during starvation.

III. Are they formed during the katabolism of the protoplasm of liver cells?

B. *Fate of Liver Fats.*

Before investigating these points certain *preliminary observations* were necessary.

1. What is the best method of extracting the fats? Soxhlet's method was adopted.

2. How much of the ether extract is composed of true 'fats?' For saponification and estimation of the 'fatty acids' the method given by Hoppe Seyler, the method of Lebedeff, and the method of Kössel and Obermüller were tested. The last was found most satisfactory.

A large series of observations shows that the fatty acid in the ether extract varies much—from 40 to 70 per cent.—averaging about 65 per cent.

3. Is the proportion of fatty acids the same in the liver as in the ordinary fats of the body? Lebedeff's method was used. The solid acids (palmitic and stearic) are to oleic acid on an average as 1 to 1·5; in fishes, 1 to 3·5. This agrees with one or two previous estimations. In the fats of the body Lebedeff found in a lipoma 1 to 2·37, and in subcutaneous fat 1 to 5·11.

4. Is the distribution of fats uniform throughout the liver? It is found to be so.

5. In animals in the same condition is the percentage amount of fat in the liver nearly the same? Ten observations show that the variation is usually under 5 per cent., while the difference in the amount of fatty acids is even smaller.

A. *The Source of Liver Fats.*

I. Are they directly stored from the fat in the food?

a. The amount of fats in the liver at different periods after food was estimated, and, with the exception of a somewhat doubtful increase between twenty-four and thirty hours after the meal, no change in the amount of fat could be determined. Further experiments on this subject are being carried on.

b. Does the amount of fat bear any relationship to the amount of glycogen? As a result of a large number of estimations it is concluded that the fats bear no relationship to the amount of glycogen.

II. Are they formed from the fats of the adipose tissue?

a. Much of the work already published on phosphorus poisoning tends to indicate that they are so formed.

b. During starvation the amount of fats in the body falls to a much greater extent than the liver fats, which undergo a comparatively small reduction.

III. Are they formed during the katabolism of liver protoplasm?

In the *post-mortem* liver kept for several hours at 40° C. no change in the amount of fats has so far been determined. Further experiments on this point are required.

B. The fate of the liver fats has not so far been sufficiently investigated to justify any conclusions.

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4. *On the Measurement of Simple Reaction Time for Sight, Hearing, and Touch. By* Professor W. Rutherford, *M.D., F.R.S.*

Reaction time is the interval that elapses between the stimulation of a sense organ and a motor response. The physiological process involved consists of (*a*) an afferent factor—the stimulation of a sensory terminal and transmission of an impulse along sensory nerve-fibres to the brain; (*b*) a psychical factor involving an act of sensory perception and the voluntary production of a motor impulse; (*c*) an efferent factor—the transmission of an impulse along motor nerve-fibres, and muscular contraction. To render the reaction 'simple,' *discrimination* is eliminated from the act of perception by repeating the same sensation again and again without variation in its character; and *choice* is eliminated from the voluntary act by giving the same motor response again and again. In the author's experiments motor response was given by the right forefinger closing an electrical key. The stimulus for sight was the movement of a flag attached to a lever; that for hearing was a click given by transmitting an induction shock through a telephone; that for touch was an induction shock or a mechanical tap. The reaction time was ascertained by recording the moments of stimulation and of response on a revolving cylinder and also on a pendulum myograph, and measuring the interval by a tuning-fork. The pendulum myograph has not hitherto been employed in such experiments. It is very advantageous in experimenting on hearing and touch. Successive curves are superimposed, so that variations in the time of successive reactions are visible at a glance, and can be readily measured. By photography the record can be readily printed or thrown on a screen for lecture demonstrations. The reaction times, as measured by the author's methods, differ considerably from those of some German observers. In observations made on eight intelligent healthy men, varying in age from nineteen to sixty-two, the reaction time for sight varied from 0·1662 second to 0·2202 second, and was mostly between 0·20 second and 0·22 second. The reaction time for hearing varied from 0·1448 second to 0·1930 second, and was mostly between 0·15 second and 0·16 second. The reaction time for touch varied from 0·14 second to 0·1906 second in the different cases. The shortest touch reaction time is that following stimulation of the cheek: it varied from 0·141 second to 0·157 second. When the skin of a finger was stimulated the reaction time varied from 0·142 second to 0·190 second, but was mostly from 0·15 second to 0·18 second in the different cases; there was no evident relation between age and length of reaction time in the cases under observation. In a limb the reaction time is generally longer the greater the length of sensory nerve traversed by the impulse; but there may be considerable variations in the reaction times for different districts in the field of touch not explicable by difference in the length of sensory nerve traversed, but probably due to difference in the closeness of relation between centres for tactile sense in the brain and the motor centre for the hand. It may therefore happen that a response is given sooner by the hand when its skin is stimulated than when the mucous membrane of the tongue is stimulated, although in the latter case the impulse has a much shorter tract of sensory nerve to traverse. When the right hand gives the response the shortest reaction times for hearing and touch are obtained by stimulating the right ear and right side of cheek. In the experiments on sight both eyes were used at the same time. The influence of fatigue on reaction time and the remarkable restorative effect of tea were demonstrated in the photographs.

5. *On the Microscopic Appearance of Striped Muscle in Rest and in Contraction. By* Professor W. RUTHERFORD, *M.D., F.R.S.*

6. *On Effects of Suprarenal Extract.*
By Professor E. A. SCHÄFER, *F.R.S.*

7. *On Epithelial Changes produced by Irritation. By* D'ARCY POWER, *M.A., M.B. Oxon., F.R.C.S., Lecturer on Histology at the Royal Veterinary College.*

Mr. Power showed a series of preparations of the conjunctival and vaginal mucous membranes taken from rabbits and guinea-pigs which had been subjected to mechanical and chemical irritation. Many of the epithelial cells presented appearances which were identical with those described as being parasitic when they were met with in cancer. The changes in the epithelium were summarised as a general vacuolation of cells; various forms of intracellular œdema; epithelial 'pearls,' collections of leucocytes, and the spaces left after these leucocytes had migrated. These changes he had already described and figured in the 'British Medical Journal' for 1893. The series of preparations shown on the present occasion indicated that many squamous epithelial cells had the power of phagocytosis, for in no other way could the remarkable intracellular appearances be explained, and he showed cells containing a leucocyte, and others containing a microcyte. Partial necrosis of the cell also took place as a result of irritation, and there was an invasion of large eosinophile cells into the conjunctival epithelium.

The full text of the paper, with illustrations, is published in the 'Journal of Pathology and Bacteriology' for October 1894.

SATURDAY, AUGUST 11.

The following Papers were read:—

1. *On Vowel and Consonant Sounds. By* D. L. HERMANN, *Professor of Physiology in the University of Königsberg.*

2. *On an Aerotonometer and a Gas-burette.*[1]
By Professor Léon Fredericq, *Liège.*

The air which enters the lung is rich in oxygen (20·9 per cent.) and poor in carbonic acid (0·03 per cent.). On leaving the lung it is relatively poor in oxygen (18 per cent. in dogs) and rich in carbonic acid (2 to 3 per cent. in dogs). It has given up oxygen to the blood and received from it carbonic acid.

What is the cause of this gaseous exchange between the blood and the air of the pulmonary alveoli? Pflüger believed that he had succeeded in explaining this exchange by the simple laws of gaseous diffusion—laws in virtue of which each gas passes from a medium in which its tension is high towards a medium in which its tension is low. The determinations of carbonic acid tension made by Pflüger's pupils simultaneously in the blood by means of the aerotonometer and in the air of the pulmonary alveoli were in complete harmony with this explanation.

Christian Bohr has come to a different conclusion on this subject. According to him, gaseous diffusion alone does not explain the exchange of gases between the blood and the air of the lung. Bohr has found in several of his experiments the air of the alveoli richer in oxygen and poorer in carbonic acid than in the arterial blood leaving the lung. According to Bohr, the tissue of the lung plays an active part in respiration: the pulmonary epithelium excretes carbonic acid by a true secretion process, and passes oxygen into the blood, not in accordance with the laws of diffusion, but against these laws.

I have recently taken up this subject again, and in doing so have made use of the aerotonometer exhibited to the Section, which is a modification of the instrument of Pflüger. The apparatus consists essentially of a sufficiently long vertical tube, connected above with the carotid of a living animal (an anæsthetised dog), and below with a vein. The arterial blood (which has previously been rendered incoagulable by the injection of propeptone) flows continuously over the inner surface of the tube of the aerotonometer, which is kept at a temperature of 38° C. If the experiment lasts sufficient time for the attainment of equality of tension of the gases of the blood and those enclosed in the aerotonometer, an analysis of the latter gases will indicate the tension of the gases of the blood. Bohr believed that equality of tension could be reached in a few minutes, and thus obtained erroneous results. I have found that nearly two hours are necessary before equality of tension is reached. One finds then that the air of the aerotonometer contains 2 to 3 per cent. of carbonic acid and 12 to 14 per cent. of oxygen, representing the tension of these gases in the blood in accordance with the diffusion theory. I have also found that if one lets the animal breathe pure or nearly pure oxygen, the tension of this gas in the arterial blood may exceed 60 per cent. of an atmosphere. The animal, nevertheless, shows only a slight tendency to apnœa; it continues to breathe. Apnœa is thus not a necessary result of a very high oxygen tension in arterial blood. This is a fact which seems to me very important in connection with the theory of apnœa.

The gas analyses were made with a gas-burette, shown to the Section, which is simply a modification of that of Hempel. The burette is drawn out at the level where the readings are made, so as to permit of reading easily to ·02 or ·01 c.c. The confining liquid is water (and not mercury), which gives rise to scarcely any error, diffusion of gases into liquids being so slow. The carbonic acid is absorbed by potash solution, the oxygen by phosphorus.

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3. *On Local Immunity. (A Preliminary Communication.)*[2]
By Louis Cobbett, *M.A., M.B., F.R.C.S., and* W. S. Melsome, *M.A., M.D.*

If it be true, as there seems reason to believe, that recovery from an infectious disease is due to certain changes in the body, which make it more resistant to the micro-organisms which cause that disease, and that the same changes are also the cause of subsequent immunity, the well-known fact that in erysipelas the parts first attacked may be recovering while the disease is spreading elsewhere would lead us to suspect that these parts have learnt to resist the streptococcus while the rest of the body is still susceptible.

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[1] For further details see *Centralblatt für Physiologie*, 1893, vii. p. 26; 1894, viii. p. 34.

[2] A full report is published in the *Journal of Pathology*, 1894.

To inquire whether erysipelas confers any such local immunity was the object of the following experiments:—

Fourteen rabbits which had recently suffered from erysipelas in the right ears were again inoculated with the streptococcus, this time in both ears. In each case a control animal, inoculated at the same time, suffered from typical erysipelas. The results were as follows: *Left ears.*—In four, only a little redness about the seat of inoculation. In four, erysipelas commenced, but aborted on the third or fourth day. In six, typical erysipelas. *Right ears.*—Inflammation rapidly appeared, affected the whole part, and subsided in twenty-four to forty-eight hours. Culture experiments, which invariably revealed the presence of streptococci in the early stages of true erysipelas, showed that micro-organisms were absent from the inflamed right ears. Thus all the right ears showed themselves to be immune, while nearly one half the left ears proved as susceptible as those of the control animals. Hence we conclude that the first attack of erysipelas had conferred a very complete local immunity. That erysipelas confers some degree of general immunity is already well known from the work of Fehleisen, Roger, and others.

Further experiments showed that this local immunity lasted only so long as any thickening remained in the ears after erysipelas. Its duration depended, therefore, on the severity of the first attack.

The inflammation which resulted from inoculations of ears previously affected we thought to be a reaction against the poisons actually introduced, and not due to the vital activity of the cocci, because we could obtain no evidence that these had multiplied and invaded the ear. This opinion was put to the test by injecting into both ears of animals, which had recently suffered from erysipelas in one ear, small quantities of concentrated filtered cultures, and in one case the streptococci themselves destroyed by heat. In these experiments a somewhat violent inflammation, of short duration (two to three days), resulted in the right ears, and a less severe but more prolonged inflammation in the left. An important difference was in the time of onset of this inflammation, which in the previously affected ears appeared many hours earlier than in the others; a difference similar to that which had already been observed to result from the inoculation of living cocci under the same conditions. Thus it appears that parts which have recently suffered from erysipelas become more quickly and intensely inflamed when subjected to the action of the products of the streptococcus than do other parts of the same animal. And when we remember that this tendency to inflammation goes hand in hand with a notably greater resistance to the living microbe, we are led to regard it as beneficial in its action, and an important factor of local immunity; an opinion in harmony with that already expressed by Metchnikoff and others—viz. that inflammation is a protective process.

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4. *A Form of Experimentally-produced Immunity.*

By J. Lorrain Smith, *M.A.*, *M.D.*, *and* E. Trevithick, *M.B.*

The occurrence of fibroid changes in the lungs when these are due to the irritant effect of inhaled dust is, according to clinical authorities, associated with increased liability of the lungs to infection by the tubercle bacillus. On the other hand, there is much clinical as well as experimental evidence to show that the condition of inflammation in the tissues is in general accompanied by an increased power of resisting the invasion of microbes.

The following experiments are brought forward to show that, in its early stages, the inflammation due to irritating dust in the pleural cavity increases the difficulty of infecting the animal in this locality with the bacillus pyocyaneus. The experiments were made on guinea-pigs and rabbits.

The dust (pounded glass) was placed in a bottle containing a quantity of water. This was sterilised, and before injection the dust was stirred up and mixed with the water. About 1·5 c.c. of this mixture was drawn into the injecting cannula. The cannula consisted of a piece of glass tubing drawn to a sharp point, with a lateral opening a short distance behind the point. This opening was made of a size just sufficient to allow the dust to pass easily through. No force was needed in the injection, the negative pressure due to the inspiratory act being sufficient to suck the moisture into the cavity.

The effects due to the simple dust were observed in several animals of both kinds. These consisted in hyperæmia of the lung with exudation of fluid and red cells into the alveolar spaces. There was also exudation of fluid into the pleural cavity in several instances, and it contained usually a considerable number of red cells also. To some extent the epithelium covering, the pleural surface of the lung, was thrown off into the fluid.

The dust was rapidly absorbed into the lymphatic vessels, and could be seen, even after twelve hours, as small round yellowish patches in the pleural membrane. These when examined microscopically were found to contain large numbers of glass particles.

The injection of the bacillus pyocyaneus followed after a time, varying from one to twenty-six days.

In the following table we have a summary of the observations.

Guinea-pigs.—Six animals, with controls:—

Two recovered completely.

Three survived the control animals for a period.

One was a contradictory instance, for this died sooner than the control animal.

Rabbits.—Seven animals, with controls:—

Two recovered, the controls dying on the second day after infection.

Three survived the controls in two cases one day, and in one case eight days.

Two cases in which the bacillus was injected into the opposite pleural cavity. One died with the control, the other earlier.

The conclusion which is derived from these experiments is that the early stages of inflammation confer a certain amount of immunity on the pleural cavity in which the inflammation has been set up. It does not seem to vary in its protective power during the first month or so after the inflammation has been set up. In those instances where there was not complete recovery it was usually found that bacilli occurred to a much greater extent in the pleural exudation of the control animals than in that of those infected with glass dust.

The death of the last two rabbits points to the fact that probably the protection conferred is strictly localised in the inflamed tissues.

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5. *On the Changes in Nerve Cells due to Functional Activity.*
By GUSTAV MANN, *M.D.*

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6. *On the Effect of Gravity on the Circulation.* *By* DR. L. HILL.

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7. *Experimental Inquiry upon the Different Tracts of the Central Nervous System.* *By* F. W. NUTT, *M.D.*

The origin and termination of the fibres of the fillet were investigated by noting the degeneration resulting from unilateral separation of the nuclei of Goll and Burdach from the arciform fibres issuing therefrom. The degenerated arciform fibres were traced by Marchi's method into the opposite interolivary layer, and thence into the fillet. The degenerated fibres of the fillet were followed mos distinctly into the optic thalamus, passing through the striæ medullares. They could not be traced beyond this to the cortex.

The author also gave a preliminary account of some experiments relating to the antero-lateral tract of Gowers. He considers his researches so far show that it is a crossed tract, consisting in the main of fibres proceeding to the middle lobe of the cerebellum, but also containing a few scattered fibres proceeding from the posterior roots, and apparently ending in the corpora quadrigemina.

MONDAY, AUGUST 13.

The following Papers were read :—

1. *On the Mechanical Theory of Lymph Formation. By* DR. STARLING.

2. *On Lymph Formation. By* WALTER S. LAZARUS-BARLOW, *M.D.*

During the course of experiments performed in the Pathological Laboratory, University of Cambridge, for the investigation of the pathology of the œdema which accompanies passive congestion the author was led to examine certain of the conditions that modify the flow of lymph in the normal animal.

He introduced a cannula into one of the lymphatics of the hind limb of a dog, and, as far as possible, ligatured all remaining lymphatics. The limb was then emptied as completely as possible of lymph by rapid and firm squeezing from the paw upwards, and an observation was immediately commenced upon the amount of lymph formed in the limb during one hour. The animal was under A.C.E. mixture and was kept absolutely at rest, excepting that coagulation of the lymph in the cannula was prevented by occasional gentle squeezing of the limb. Immediately before the expiry of the hour the limb was again emptied of lymph as completely as possibly by firm squeezing. The lymph was collected in carefully graduated tubes, and the amount thus obtained was regarded as the normal for the individual.

An elastic ligature previously arranged round the limb was then tightened to such an extent as, it was known from other experiments, would raise the pressure in the femoral vein from the normal 4–5 mm. of mercury to 25–35 mm. Exactly the same processes were carried out during the collection of lymph under these modified conditions as were described for the normal conditions. The duration of increased pressure was one hour. Lastly, the elastic ligature was removed, and the amount of lymph formed in an hour under normal conditions was again estimated.

The limb was therefore as free as possible from lymph immediately before beginning and immediately before ending each of the three portions of the investigation.

The author found that the amounts collected in the three periods were either absolutely identical, or that the amount collected during the period of high venous pressure was less than that collected when the pressure was normal. On no occasion did he find that an increase of venous pressure was accompanied by an increase in the amount of lymph-flow.

The amount of lymph-flow, however, being the product of two factors—viz. the amount of fluid poured out by the blood-vessels and any modifications in that amount introduced during the sojourn of the lymph in the tissues—it was necessary before concluding that an increase of lymph-formation does not accompany an increase in venous pressure to determine whether an excessive amount of fluid had accumulated in the tissues in the form of œdema, since it was possible that the increased venous pressure might have caused an increased outflow of fluid from the capillaries and venules, and that that increased outflow might not have shown itself in an increased flow from the lymphatics, because it was in part stored up in the tissues as œdema fluid. To determine this point observations of the specific gravities of arterial blood and blood-plasma, venous blood and blood-plasma, of muscle and of skin were taken before and after the pressure in the femoral vein was raised. It was found that these underwent no changes whatever, either in the affected limb or in other parts of the body (with the exception of a rise in the specific gravity of the venous blood and blood-plasma in the affected limb) during venous obstruction, which caused a rise of pressure in the femoral vein, varying in individual cases from 48–75 mm. of mercury. The modification of specific gravity of the venous blood and blood-plasma in the affected limb manifestly depends upon its lengthened sojourn in the limb.

The author concludes, therefore, that increase of venous pressure in a limb for one hour not only does not cause an increase of lymph-flow from the lymphatics, it does not even cause an increased passage of fluid through the blood-vessel walls.

Independently, however, of the venous pressure, the amount of lymph-flow is increased when the tissues have been starved for some time or are overstocked with their own katabolic products.

The following conditions were investigated:—

1. Before and after prolonged complete anæmia (three hours), produced by an Esmarch's bandage.

2. Before and after hæmostasis, or complete cutting off of the limb, with whatever blood and lymph it might contain, from the rest of the body by means of a tight elastic bandage for one hour.

3. Before and after stimulation of the sciatic nerve, while the limb was completely anæmic and persistence *in situ* of the katabolic products, the whole lasting one hour.

All these conditions are followed by arterial dilatation in the part; and, inasmuch as arterial dilatation subsequent to section of the sciatic nerve was found by the author to be unaccompanied by any modification in the amount of lymph-flow, he concludes that the increase occurring under the conditions given above is immediately conditioned by the excessive needs of the tissues.

Under extreme conditions, such as those just given, the effect of an increase of venous pressure is markedly different from what it is when such conditions have not been introduced, for now an increase of venous pressure *is* accompanied by an increase in the lymph-flow, while the lymph-flow diminishes when the venous pressure is again allowed to return to normal. In other words, the lymph-flow now varies *directly*—the author cannot say whether it be *proportionately*—with the venous pressure. It now, therefore, bears some resemblance to mechanical filtration. Inasmuch, however, as an obstruction to the outflow of blood from the venous side itself intensifies the necessity of the tissues by damming up in them the waste products they are so anxious to get rid of, this resemblance to mechanical filtration may, after all, be only apparent.

The author concludes, therefore, that lymph-formation does not depend upon purely mechanical conditions of the circulation, but he regards it as dependent upon the needs of the tissues: those needs are, in some as yet unrecognised way, made known to the circulatory apparatus, and lead to variations in the amount of blood-flow through the part, in extreme cases active arterial dilatation of the most marked kind being induced. In such extreme cases, further, the lymph-flow varies directly with the venous pressure, and there is a resemblance to mechanical filtration; but there are reasons for supposing that this resemblance is an apparent and not a real one.

3. *On the Innervation of the Portal Vein.*

By W. M. Bayliss *and* Dr. Starling.

4. *On some Vaso-dilator Reflexes.* *By* W. M. Bayliss.

5. *On the Production of Heat in Hibernating Animals.*
By RAPHAEL DUBOIS, *Professor of Physiology in the University of Lyons.*

For several years the author has investigated the production of heat in the marmot in order to find out what part of the nervous system is essential for the rapid production of heat which takes place when the animal wakes up from its winter sleep.

Section of the spinal cord at the level of the fourth cervical vertebra prevents the animal from raising its temperature. Destruction of the grey substance of the brain produces a similar effect. If the section of the spinal cord be made at the level of the seventh cervical vertebra the animal grows warm slowly and incompletely; but if the operation be performed between the fourth and fifth dorsal vertebræ, then the curve of the rise of temperature presents the normal form. There is therefore a limited portion of the cord, between the fourth cervical and the first dorsal vertebræ, through which pass the centripetal or centrifugal, or both, impulses, placing the cortex of the cerebral hemispheres in communication with the rest of the organism. The pathway is through the grey substance of the spinal cord, for section of the antero-lateral or of the posterior columns does not prevent the animal from producing heat, whereas destruction of the grey matter in this limited portion of the cord produces the same effect as total section. This operation produces immediate loss of the power of movement and conscious sensibility in the greater part of the body; but the absence of the capacity to produce heat must not be attributed to this sensory and motor paralysis, for section a little lower, at the fourth dorsal vertebra, does not change the normal curve of temperature.

The section of the cord at the fourth cervical vertebra abolishes, on the one hand, the contractions of the thoracic muscles, the activity of which is very great during the rewarming and insignificant during the torpor; on the other hand, it cuts off the very important connections of the sympathetic system with the higher centres. If the cervical sympathetic be cut on both sides above the inferior cervical ganglion there is no very marked delay in the production of heat, whereas the rise of temperature is very slow and incomplete when the inferior cervical and the first thoracic ganglia are removed on both sides. These ganglia, however, are only connecting links, for the same result is obtained by section of the two splanchnic nerves or of the branches which pass directly from the abdominal sympathetics to the semilunar ganglia. Extirpation of the semilunar ganglia produces the same result as removal of the inferior cervical and first thoracic ganglia.

Experiments show that it is by acting upon the portal system that the sympathetic shares in the general process of heat production. It regulates the quantity and pressure of the blood which flows to the liver, and in this manner the production of heat in the liver and the transformation of glycogen into sugar, to be utilised for combustion when the animal awakes. The thoracic muscles become exceedingly active when the animal awakes, and thus require more glycogen or other combustible material for their contraction.

A full account of this research will shortly be published in 'Les Annales de l'Université de Lyon.'

6. *On 'Pigeons' Milk.'* *By* E. WAYMOUTH REID, *Professor of Physiology in University College, Dundee.*

John Hunter (1786) discovered the fact that pigeons feed their young for some days after hatching upon a substance resembling the curd of milk, and formed in the lateral pouches of the crop of both cock and hen. This method of feeding is as yet only known in this tribe of birds.

Claude Bernard (1859) studied the nature of the substance, and found that microscopically it consisted of masses of the epithelial scales of the crop mucosa loaded with fat globules. An analysis made for Bernard by Leconte gave—

'Casein' and salts	23·23
Fat	10·47
Water	66·30

No sugar was present—a fact noted also by Hunter.

Hasse (1865) and more recently Max Teichmann (1889) have also written on the subject from the histological point of view.

The lateral pouches of the crop of the non-breeding pigeon are not glandular; the epithelium is stratified and free from fat, the submucosa provided with small vascular papillæ.

The change in the crop membrane necessary for the formation of the 'milk' commences during the incubation of the eggs, and though not visible to the naked eye till two or three days before hatching, makes itself evident by the appearance of fat-droplets in the cells ten days before this event. The main change consists in a great thickening of the epithelium, accompanied by rugose folding with reticulation, while at the same time the structure becomes enormously vascular and capillaries penetrate the epithelial layers (Hasse and Teichmann).

Small pellets of curd-like matter form in the pits of the reticulated surface, and as soon as the young are hatched these are transferred by the parents to the crops of the 'squabs,' often to the extent of 40 per cent. of the weight of the bodies of the young.

In its histological features the process of formation of the 'milk' resembles more closely that of the formation of sebum than of milk, for whole masses of fat-holding cells are cast off from the walls of the pits in the membrane; yet, unlike the sebaceous process, the nuclei of the cells persist.

Interpapillary involutions, then, of the thickened stratified epithelium of the crop act as sebaceous glands during the period of formation of the 'milk.'

This period lasts for from seven to nine days after hatching, and the maximum of activity is reached about the second day after hatching.

The young are fed almost exclusively on this substance for the first three days, though a few crushed grains are also supplied by the parents. The parents appear to crush the grains at first, though later they are supplied whole. This fact is accounted for by the condition of the gizzard membrane of the early 'squab,' for the horny secretion of the tubular glands of the mucosa takes some days to consolidate. No digestive ferments are supplied by the parents along with the 'milk,' and the proventriculus of the young 'squab' pigeon, even at twelve hours, is rich in proteolytic ferment, its glycerine extract digesting fibrin with ease. The crops of neither adult (breeding or non-breeding) nor young birds form any amylolytic or proteolytic ferment; in both cases, however, multitudes of bacteria and cocci are present, and the acidity of the contents (reaction of Uffelmann, but no reaction with phloroglucin and vanillin) is probably due to lactic fermentation. The pancreas of the 'squab' is capable of digesting starch at the time of hatching.

In the 'squab' the cell bodies of the 'milk' are dissolved off by the secretion of the proventriculus, and the fat set free in the gut is found in the cells of the villi, and also in the leucocytes of the blood. The fæces of the 'squab' are fat-free, though at an early stage they contain considerable proteid.

Though sugar is undoubtedly absent from the 'milk,' a young 'squab' pigeon before it has received any food contains sugar. In one case a triple alcoholic extract of a minced and finally pulverised 'squab' yielded over ·2 per cent. of its body weight of reducing sugar, while a subsequent triple aqueous extract gave ·16 per cent. of the body weight of an amylose yielding sugar on boiling with dilute sulphuric acid. This amylose struck no colour with iodine, and attempts to demonstrate glycogen in the bodies of unfed 'squab' pigeons have failed, though the pectoral muscles of adult birds are very rich in this substance.

As regards the proteids of the 'milk,' extracts with 'normal saline solution' by trituration and digestion with thymol at 40° C. show absence of albumins, proteoses, and peptones; presence of globulin and of caseinogen (clot with rennet, with and without calcic chloride). The chief proteid, however, appears to be of the nature of nucleo-albumin (Halliburton's sodic-chloride method). Mucin is present in variable amount, and originates from the glands of the gullet below the crop. These glands enlarge and become more active during the feeding of the young.

The young pigeon is, then, fed at first upon a highly nutritious food, whose solids consist in the main of nucleo-albumin and fat. The explanation of this peculiar process lies in all probability in the fact that since pigeons rear so many broods in a season the young must be brought forward faster than could result from mere grain feeding, and hence a magnificently nutrient diet is supplied. When a cock or hen 'in milk' is separated from the young the involution of the crop changes occurs with great rapidity, for within twenty-four hours the temporary 'sebaceous glands' are loosened and cast off, the hypertrophied papillæ which lie between them being subsequently reduced. Such birds swallow their own 'milk;' their villi contain more fat than normal birds, and fatty leucocytes are seen in abundance in the blood.

Some days, however, after separation, though the gross changes in the crop membrane have disappeared, fatty cells are found in the epithelium.

The 'milk' in the crops of such separated birds is also in finer particles than normal and poorer in solid constituents.

A few quantitative analyses, kindly made for me by my colleague Mr. F. J. Hambly, are appended:—

—	A. From crop of a 4-hour 'squab' pigeon		B. From crop of a 12-hour 'squab' pigeon		C. From crop of a 51-hour 'squab' pigeon		D. From crop of hen feeding 4 'squabs' for 63 hours without aid of cock	
	% Milk	% Solids	% Milk	% Solids	% Milk	% Solids	% Milk	% Solids
Water . . .	79·33	—	77·91	—	73·98	—	84·51	—
Fat	7·74	37·4	8·15	36·9	9·32	35 8	3·99	25·8
Ash . . . } Proteids . }	12·93	62·6	{ 1·11 { 12·83	5·0 58·1	1·06 15·64	4·1 60·1	·91 10·59	5·9 68·3
—	100·00	100·00	100 00	100·0	100·00	100·0	100·00	100·0
Total solids .	20·67	—	22·09	—	26·02	—	15·49	—

7. *On the Structure of Striped Muscle. By* Professor J. B. HAYCRAFT.

The cross-striping of muscle is due to the form of the fibril and not to its internal structure. The fibril is like a beaded rod, and the striping is the optical expression of this. The proof of this is obtained by stamping moist collodion with a piece of muscle. The collodion stamp preserves the form of the fibrils, and shows identically the same cross-striping to the minutest detail. The stamps and their photographs were demonstrated. In one a fibril had been stamped in which one part alone was in the condition of contraction, and every detail of the striping, both in the relaxed and contracted conditions, was identically reproduced.

TUESDAY, AUGUST 14.

1. A joint meeting with Section A was held to discuss the following Papers
days Professor Oliver Lodge, F.R.S.
the later 1.—*Experiments illustrating Clerk Maxwell's Theory of Light.*
as yet only 2.—*An Electrical Theory of Vision.*
Claude Be

The following Papers were read:—

2. *On a Modification of Golgi's Methods. By* Oliver S. Strong, *of Columbia College, New York.*

Golgi's methods may be divided into two principal heads: (1) The *sublimate* method, consisting essentially of hardening in bichromate of potash followed by immersion in bichloride of mercury. This method need not be further noted here.

(2) The *silver* methods, consisting of (*a*) the long, or slow, method, consisting of hardening for about twenty to thirty days in potassium bichromate followed by immersion in a solution of silver nitrate. (*b*) The rapid method, where the hardening is done in a mixture of bichromate and osmic acid. This is the method, slightly modified, which is so extensively used, and is the method used by Ramón y Cajal. (*c*) What may be designated the mixed method, or combined method, and consists in hardening first for a few days or a week or so in potassium bichromate, then a day or two in the osmium-bichromate mixture, and finally the immersion in the silver bath.

The rapid method is the best yet discovered for work on the peripheral terminations of nerves and for the embryonic central nervous system. For adult brains it is not so well adapted owing to the poor penetration of the osmic acid, and consequent liability to overharden the periphery while the central portions of even small pieces remain untouched. Moreover, adult brains are not well adapted for the study of the nervous or axis cylinder prolongations of the cells, owing probably to their sheath, so that on such material study by these methods would be chiefly directed to the cell bodies and their protoplasmic expansions. For such purposes the long Golgi method is eminently adapted.

While the long Golgi method avoids the disadvantages, including the expense—no small consideration where such quantities are used—of osmic acid, it has the disadvantage of requiring about a month, besides the uncertainty common to all these methods.

In order to reduce this period of time, and yet to avoid the use of osmic acid, the new method here proposed for the study of adult brains is the use of *bichromate of lithium* instead of the bichromate of potassium, with the same percentages. I have found that tissues (small pieces) placed in the former reach the favourable stage of hardening for the silver impregnation in the course of one to two days, instead of twenty to thirty days. It passes through this favourable period quite rapidly, but the whole process is reduced to such a short time that it is rendered much less tedious. The pictures yielded by this process, judging from the few made thus far, are certainly fully equal to those prepared by the other methods.

The subsequent treatment is as in the other methods, *i.e.*, the piece of tissue is rinsed in strong alcohol, cut free hand or gummed on a block without any imbedding, and cut with a microtome. The sections are washed in several changes of strong alcohol, cleared in oleum origanum *Cretici*, washed briefly in xylol, and mounted in dammar or Canada balsam, thinned with xylol, without a cover slip.

It would be interesting to ascertain how well adapted this new hardening reagent would be for preparing the central nervous system for other methods of staining, *e.g.*, the Weigert method.

3. *On an Attempt to supply Motor Power to the Muscles of the Larynx from a New Source. By* Veterinary-Captain F. Smith, *F.R.C.V.S., F.I.C., Army Veterinary Department, Aldershot.*

The subject used in these observations was the horse, the inquiry having in view the possible relief of the respiratory distress so common in this animal as the result of laryngeal paralysis.

The new source of nerve supply was sought for in the spinal accessory. The recurrent and spinal accessory were exposed and divided, and the proximal end of the accessory was sutured to the distal end of the recurrent.

The only convenient test which could be employed to ascertain what progress the animal was making after the operation was that afforded by galloping it.

In one case, a few months after the above nerves had been united, there was only a slight harshness in the breathing during inspiration, even when the horse was severely 'pressed;' whereas, unless nerve impulses were passing down the accessory and through the recurrent to the larynx, the animal should have suffered from intense dyspnœa, as the whole of the dilator muscles of one side of the larynx would have been paralysed.

In a second case, the recurrent, before suture to the accessory, was known to have been degenerated for at least two years. This animal continued to have noisy breathing up to the time it was destroyed (twelve months after the operation), but it was unaccompanied by distress.

In the first case only an ordinary *post-mortem* examination was made to ascertain whether the nerves were united; in the second horse the nerves were stimulated electrically immediately after death, and a careful microscopical examination of the parts made.

On stimulating that portion of the recurrent in connection with the larynx the muscles actively responded; on stimulating the accessory well above the nodule uniting it with the recurrent, the muscles of the larynx again actively responded.

These observations were repeated several times by Professor Delépine, of Manchester (who kindly associated himself with me as an independent observer in the *post-mortem* examination), and the results are beyond doubt.

The muscles of the larynx of the above case, supplied by the accessory-recurrent nerve, were smaller and decidedly paler in colour than the healthy ones on the opposite side; on directly stimulating the muscles every portion of them actively responded to a weak current.

Professor Delépine examined the united nerves microscopically, and found in the recurrent between the point of union and the larynx small bundles of medullated nerve fibres and an amount of epi- and peri-neurium larger than normal. The place occupied by the old funiculi was quite distinct, but the nerve fibres occupied only a portion of the spaces thus indicated. The nerve fibres were all of smaller diameter than normal; most of them had a very thin myelin sheath which stained well with osmic acid. Professor Delépine was of opinion from this and the other observations that partial regeneration had certainly taken place, and that regeneration was progressing at the time of death.

By the tests employed it was not possible to say whether co-ordination of the laryngeal muscles occurred, but it is proposed in future observations to examine closely into this subject, and employ the laryngoscope to ascertain whether the impulses to the larynx are sent at the right moment.

At present it would almost appear to be possible to educate a nerve centre to perform a duty it was never intended for.

4. *On the Causes and Prevention of Suffocation in Mines. By* J. S. Haldane, *M.A., M.D., Lecturer on Physiology, University of Oxford.*

Evidence was brought forward by the author that most of the deaths caused by colliery explosions and fires in the workings are due to suffocation, so that a thorough investigation of the subject is of great practical importance.

He concluded that poisoning by carbonic acid is never the cause of death in cases of suffocation by choke-damp, black-damp, or after-damp; that deprivation of oxygen is always the cause in the cases of choke-damp or black-damp, and usually the cause in the case of after-damp, although after-damp, even when much diluted, is sometimes poisonous from the presence in it of products of incomplete combustion, such as carbonic oxide or sulphuretted hydrogen. He also discussed the effects of white-damp, and drew attention to the exceedingly poisonous character of the gases from the explosion of blasting powder.

In conclusion he described and exhibited a portable apparatus for enabling miners to escape through an atmosphere of after-damp to the fresh air in the neighbourhood of the shafts, and for rescue purposes.

5. *Observations on the Effects of After-damp.*
By J. Shaw Lyttle, *M.D.*

The writer gave a detailed account of the symptoms presented by those who were found alive after the recent explosion at the Albion Steam Colliery.

6. *Experiments on Memory.* *By* W. G. Smith, *M.A.*, *Ph.D.*

If we examine any case of ready and accurate recollection taken from our daily experience, we find it difficult, if not impossible, to say how much of this accuracy is due to such factors as the interest which the experience aroused, the attention which we paid to it, the amount of effort and time spent during the experience. The following experiments were carried out with the view of trying to isolate experimentally the process of attention, and showing what changes in recollection occur when various kinds of distraction of attention are introduced. The experiments were begun in the Institute for Experimental Psychology in Leipzig, and have been carried on in the Physiological Laboratory in Oxford.

After a considerable number of preliminary experiments had been made, the following method was adopted. Twelve letters of the alphabet, arranged in such a manner that intelligible words or interesting ideas should not readily be suggested, were written upon a card, so as to form three lines. The card was shown to the reagent, who then tried to learn what was written on it. In each new experiment a new combination of letters was employed. By making a sufficiently large number of observations with different persons, one can eliminate to a considerable extent the fallacies arising from varying difficulty or familiarity of the combinations employed. The card was shown in every case for ten seconds, and the reagent was required, either immediately after he ceased to see the card or after an interval of about two seconds, to reproduce as much as he could remember of what he had seen.

A distinct and at the same time fairly simple form of distraction was secured by making the reagent repeat the series 2, 4, 6, 8 . . . , or more rarely 3, 6, 9 . . . , while he was learning the letters on the card. In order that the person in charge of the experiments might have an effective control over the activity of the reagent, the series had to be repeated aloud, and each step in the addition was made to coincide with the stroke of a metronome going at the rate of sixty to seventy beats per minute. In order to compare the results of this form of distraction with those gained where the vocal organ was employed, but the mental effort involved was very small, the reagent was next required while memorising to repeat aloud with each beat of the metronome an unintelligible syllable, *e.g.*, 'la.' This form of distraction was further compared with that caused by activity of another set of muscles, viz., those employed in tapping the table with the forefinger, each tap coinciding with a beat of the metronome. Lastly, experiments were carried out to show the effect of memorising without any distraction save that due to the fact that the metronome continued to beat. These four variations were given in varying order one after the other, and were so arranged that 8, 12, 16, or 20 experiments were made in one hour.

In calculating the value of the results two methods were applied. The first resembles that employed by Münsterberg ('Beiträge zur experimentellen Psychologie'), and consists in summing up the errors committed in reproducing the letters written on the card. The errors were classified as follows:—(1) Omission of a letter; (2) insertion of a wrong letter; (3) displacement of a letter or reproduction in wrong order. According to the second method, which resembles that commonly employed in estimating the value of answers to examination papers, a greater value is assigned to letters according as they correspond more exactly to what was written on the card. A letter which was given in a wrong position or without any hint as to its position had the value 1 attached to it. When a certain imperfect knowledge of its position was present, as when it was located in the right line or in the right order in a group of letters whose correct position was unknown, the value 2 was given. Each letter counted 3 when everything was correct. Letters wrongly inserted were disregarded. From an analysis of the results given by the first method it appeared that the number of insertions does not vary very much, and only in a few cases has an important influence on the results.

All the results of over five hundred experiments made with nine observers have been analysed according to the two methods, and the results agree except in a few cases.

The general conclusion is that the memory is worst when the reagent performs the simple sum in addition (1); it is better when the distraction is caused by exercise of the vocal organ (2); that caused by movement of the forefinger (3) does not make the recollection much worse than it is when the observer is not distracted at all (4). This statement holds good with only a few exceptions for every reagent, and is confirmed by the subjective observations given in reply to the questions which were frequently asked. The average of the results given by the nine persons who assisted in the experiments is as follows: the upper line gives the values according to the first method, the lower the values according to the second method of calculation—

(1)	(2)	(3)	(4)
9·7	8·7	7·95	7·4
12·9	16·3	18·5	21·2

An analysis of the errors shows that the curve of errors of omission follows closely that of the total number of errors: the other two kinds of error are much less numerous, and do not show any very important variation. A detailed analysis of the results, together with a discussion of their meaning and value, will be given in a future number of *Mind*.

7. *On Typhoid Bacilli in Water. By* Dr. L. Olivier.

WEDNESDAY, AUGUST 15.

The following Papers and Report were read:—

1. *On some Physiological Effects of the Passage of Rapidly-alternating Currents of great Intensity through Nerve. By* Professor Oliver Lodge, *F.R.S., and* Professor F. Gotch, *F.R.S.*

2. *On a New Spring Kymograph and Polyrheotome.*
By Professor T. W. W. Engelmann.

3. *On the Production with the Capillary Electrometer of Photographic Records of Currents produced by Speaking into a Telephone. By* G. J. Burch.

4. *Report of the Committee on the Structure and Function of the Mammalian Heart.*—See Reports, p. 464.

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FOR

THE ADVANCEMENT OF SCIENCE.

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1894.

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1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.

Year of Election.

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1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
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1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 114 Eaton-square, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
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1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
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1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
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1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.

higher intellectual centres in the hope of finding any anthropological teaching. Here, at Oxford, if anywhere, we may expect to find it, and here, first among the British Universities, have we seen, since the year 1883, among the list of the subjects taught the word 'Anthropology;' but the teacher, though one of the most learned of men in the subject the country has produced, still only bears the modest title of 'Reader.' A professorship of Anthropology does not exist at present in the British Isles, and even here the subject, though recognised as a 'special,' offers little field for distinction in the examinations for degrees, and has therefore never been taken up in a thorough manner by students. Dr. Tylor's lectures must, however, have done much to have spread an intelligent interest in some branches of Anthropology, and have proved a valuable complement to the Pitt-Rivers collection, as have also the courses which have been given by Mr. Henry Balfour upon the arts of mankind and their evolution, one of which I am glad to see is announced among the advantages offered to the University Extension students at present with us. Physical Anthropology has also been taken up by Professor A. Thomson, who, I understand, gives instructive lectures upon it, open to the members of his class of human anatomy. At the opposite end almost of the subject must be mentioned the extension and organisation of the Ashmolean Museum under the care of Mr. Arthur J. Evans, which has a bearing upon some branches of Anthropology, and the foundation of the Indian Institute under the auspices of Sir Monier Monier-Williams, which must give an impetus to the study of the characteristics of the races of our great Empire in the East. Last, but by no means least in its bearing upon the origin, divisions, and diffusion of races, is the world-famous linguistic work of Professor Max Müller and Professor Sayce, both of whom have presided over this Section at former meetings of the Association.

Of the sister University I wrote thus in 1884: 'In Cambridge there are many hopeful signs. The recently appointed Professor of Anatomy, Dr. Macalister, is known to have paid much attention to Anatomical Anthropology, and has already intimated that he proposes to give instruction in it during the summer term. An Ethnological and Archæological Museum is also in progress of formation, which, if not destined to rival that of Oxford, already contains many objects of great value, and a guarantee of its good preservation and arrangement may be looked for in the appointment of Baron Anatole von Hügel as its first curator.'

Ten years have passed, and it is satisfactory to know that the teaching of Anthropology has not only been fairly established, but the subject has also found a place in the scheme of University examination. The learned Professor of Human Anatomy continues to take a wide view of his functions, giving a course during the Easter term on the methods of Physical Anthropology, and also museum demonstrations on craniometry and osteometry, by the aid of a greatly increased and continually augmenting collection of specimens. Those students who take anatomy as their subject for the second part of the Natural Science Tripos have both paper work and practical examination in Anthropology, each man having a skull placed in his hands of which he is expected to make a complete diagnostic description. For the first part of the tripos each candidate has one or more questions on the broad general principles of the subject. Professor Macalister informs me that he has always at least six men who go through a very thorough practical course with their own hands. There has also lately been established a course of lectures on the Natural History of the Races of Man, delivered during the Michaelmas and Lent terms by Dr. Hickson, of Downing College, and Baron von Hügel gives a course of museum demonstrations on the weapons, ornaments, and other objects in the Ethnological Museum, which is open to all students, and of which many take advantage.

In London, owing to the chaotic condition of all forms of higher instruction, which has been brought so prominently into notice by the universal demand for a teaching University (an aspiration which the labours of the late Gresham Commission certainly seem to have brought nearer to realisation than ever appeared possible before), all systematic anthropological teaching has been entirely neglected. The great collections to which I have already alluded, that of arts and customs at the British Museum, and that of osteological specimens at the Royal College of

Surgeons, have by their steady augmentation done valuable service in preserving a vast quantity of material for future investigation and instruction, and students have at present all reasonable facilities for pursuing their own researches in them. Lectures have never formed any part of the official programme of the British Museum, but at the College of Surgeons it is otherwise, and though the contents of the collections are specially indicated as the subject on which they should be delivered, for the last ten years at least, Anthropology, notwithstanding the magnificent material at hand for its illustration, has had no place in the annual syllabus. It is also entirely ignored in the examination scheme of the University of London, an institution which prides itself as being on a level with modern educational requirements; and the managers of the new Imperial Institute, casting about in all directions for some worthy object to occupy their energies and their spacious buildings, do not appear to have taken into serious consideration the value to the world and the appropriateness to their original design of a great central school of Anthropology, from which might emanate a full and satisfying knowledge of the characteristics of all the various races of which the Empire is composed.

In Scotland the recent Universities Commission has recognised Physical Anthropology as a branch of human anatomy in their scheme for graduation in pure science, the examination on this subject embracing a knowledge of race characters as found in the skull and other parts of the skeleton, in the skin, eyes, hair, features, and the external configuration of the body generally; the methods of anthropometrical measurement, both of the living body and the skeleton; the possible influence of use and of external surroundings in producing modifications in the physical characters of man, and an acquaintance with the 'types' of mankind and the structural relations of man to the higher mammals. These regulations came into operation in the University of Edinburgh in 1892, and in accordance with them Professor Sir William Turner delivers a special course of twenty-five lectures on Physical Anthropology, and in addition ten practical demonstrations on osteometry. The museum under his charge has greatly increased of late in number and value of the specimens. But 'Human Anatomy, including Anthropology,' being only one of a series of nine subjects in any three or more of which a final science examination on a higher standard has to be passed, there is not at present any considerable number of students who take it up, and the other Scotch Universities have not yet thought it necessary to establish distinct courses of Physical Anthropology, although it is becoming more and more a regular part of the anatomical teaching to advanced students.

For the following account of what is being done to further the knowledge of our subject in the sister isle I am indebted to Professor D. J. Cunningham. The only place in Ireland where anthropological work is done is Trinity College. For many years those in charge of the museum have been collecting skulls, and they were fortunate in obtaining the greater part of Sir William Wilde's collection. To these great additions have been recently made, principally in the form of Irish crania from different districts. All the anthropological specimens are lodged in one large room, which is also used as an anthropometric laboratory. Though there has never been any systematic teaching of Anthropology in Trinity College, Dr. C. R. Browne (Professor Cunningham's able assistant), who takes charge of the laboratory, attends for two hours on three days a week, and gives demonstrations in anthropological methods to any students who are interested in the subject. The laboratory was opened in June 1891, the instruments being provided by a grant from the Royal Irish Academy, and about 500 individuals have already been measured, the greater number of them students of the College. This is, however, only part of the work carried out by the laboratory. Every year the instruments are taken to some selected district in Ireland, and a systematic study of the inhabitants is made. The Aran Islands, and also the islands of Inishboffin and Inishshark, have been already worked out, and this year excursions are organised to Kerry, to a district in Wicklow, and to another in the West of Ireland. The Academy makes yearly grants to the Committee for carrying on this work, the results of which have been published in admirable memoirs by Professor A. C. Haddon and Dr. C. R. Browne. The Science and Art Museum in Dublin, under the direction of Dr. V. Ball, contains a small collection, arranged with a view to general instruction, showing by means of skulls and casts the physical characteristics of the different races of man, those of each race being explained by a short printed label, and its range shown on a map.

Though the development of anthropological science has thus not been greatly advanced, in this country at least, by means of endowments, or by aid of the State or, till very recently, by our great scholastic institutions, but has been mainly left to the unorganised efforts of amateurs of the subject, its progress in recent years has been undeniably great. I will give an instance of the strides that have been made in one of its most important branches.

Physical or Anatomical Anthropology, or the study of the modifications of the human body under its various aspects, the modifications dependent upon sex and age, the modifications dependent upon race, and those dependent upon individual variability, studied not many years ago in a vague and loose manner, has gradually submitted to a rigorous and, therefore, strictly scientific method of treatment. The generalities which were formerly used to express the differences that were recognised between the various subjects compared with each other have been replaced by terms conveyed in almost mathematical precision. No one acquainted with the history of the development of this branch of Anthropology can fail to recognise how much it was accelerated by the genius of Broca, and the school which he established in France, although all cultivated nations are now vying with each other in the practice of exactitude in anthropological research, and the time seems rapidly approaching when a common agreement will be arrived at, by which all the observations which may be made, under whatever diverse circumstances, and by whatever different individuals, will be available for comparison one with another.

This branch of our science has received the name of 'Anthropometry.' Although, as the name implies, measurement is one of its principal features, it includes such other methods of comparison as can be reduced to a definite standard, or to which definite tests can be applied, such as the colour of the hair, eyes, and complexion, the form of the ear and nose. The great desiderata that have been sought for, and gradually attained, in measuring either the skeleton or the living person have been two in number: 1. Exact definition of the points between which the measurements should be taken. 2. Exact methods and instruments of measurement. In both these cases the object looked for has been not only that the measurements taken by the same observer at different times and under different circumstances should coincide, but also that those taken by different observers should be comparable. These requirements seem so simple and natural at first sight that the majority of persons whom I am addressing will wonder that I should allude to them. Only those who are seriously occupied, or perhaps I should rather say, only those who were seriously occupied a few years ago, with the endeavour to solve these problems can have any idea of their difficulty. The amount of time and labour that has been spent upon them is enormous, but the result has, I think, been quite commensurate with it.

We have attained at last to methods of measurement and standards of comparison which, in the hands of persons of ordinary intelligence, and with a moderate amount of training, will give data which may be absolutely depended upon. From these we hope to be able to formulate accurate information as to the physical conformation of all the groups into which mankind is divided, and so gradually to arrive at a natural classification of those groups, and a knowledge of their affinities one to another.

But the exact methods of modern Anthropometry are not only important on account of the aid they give in studying the race characteristics of man. As has so often happened when scientific observation has been primarily carried out for its own sake, it ultimately leads to practical applications undreamt of by its earlier cultivators. The application of Anthropometry not to the comparison of races, but to elucidate various social problems—as the laws of growth, of heredity, of comparative capacities of individuals within a community, and the effects of different kinds of education and occupation, as worked out first by Quetelet in

Belgium, and subsequently by Francis Galton, Roberts, and others in this country—and its still more concrete application as an aid in administering justice by methods perfected by Bertillon in France, are striking illustrations of the practical utility of labours originally undertaken under the influence of devotion to science pure and simple.

The importance of being able to determine the identity of an individual under whatever circumstances of disguise he may be presented for examination has, of course, long been apparent to all who have had anything to do with the administration of the criminal law, and rough and ready methods of recognition, depending mainly upon the more or less acute faculty of perception and recollection of differences and resemblances, possessed by the persons upon whom the duty of identification has devolved, have long been in operation. The general conformation, height, form of features, and colour of complexion, hair, and eyes, have also been noted. Much additional assistance has been obtained by the registration of definite physical characteristics, the results either of natural conformation, or of injury, such as mutilations, tattoo-marks, and scars, inflicted by accident or design. The application of one of the most important scientific discoveries of the age, photography, was eagerly seized upon as a remedy for the difficulties hitherto met with in tracing personal identity, and enormous numbers of photographs were taken of persons, the peculiarities of whose career led them to fall into the hands of the police, and who were likely to be wanted again on some future occasion. No doubt much help has been derived from this source, but also much embarrassment. Even among photographic portraits of one's own personal friends, taken under most favourable circumstances, and with no intention of deception, we cannot often help exclaiming how unlike they are to the person represented. With portraits of criminals, the varying expression of the face, changes in the mode of wearing the hair and beard, differences of costume, the effects of a long lapse of time, years perhaps passed in degradation and misery, may make such alterations that recognition becomes a matter at least of uncertainty. That photographs are extremely valuable as aids to identification, when their true position in the process is recognised, cannot be doubted; but as a primary method they have been found to be quite inapplicable, owing partly to the causes just indicated, but mainly to the difficulty, if not impossibility, of classifying them. The enormous expenditure of time and trouble that must be consumed in making the comparison between any suspected person and the various portraits of the stock which accumulates in prison bureaus may be judged of from the fact that, in Paris alone, upwards of 100,000 such portraits of persons interesting to the police have been taken in a period of ten years.

The primary desideratum in a system of identification is a ready means of classifying the data upon which it is based. To accomplish this is the aim of the Bertillon system. Exact measurements are taken between certain well-known and fixed points of the bony framework of the body, which are known not to change under different conditions of life. The length and breadth of the head, the length of the middle finger, the length of the foot, and the length of the forearm, are considered the best, though others are added for greater certainty, as the height, span of arms, length of ear, colour of eyes, &c. All these particulars of every individual examined are recorded upon a card, and by dividing each measurement into three classes, long, medium, and short, and by classifying the various combinations thus obtained, the whole mass of cards, kept arranged in drawers in the central bureau, is divided up into groups, each containing a comparatively small number, and therefore quite easily dealt with. When the card of a new prisoner is brought in, a few minutes suffice to eliminate the necessity of comparison with any but one small batch, which presents the special combination. Then photographs and other means of recognition, as distinctive marks and form of features, are brought into play, and identification becomes a matter of certainty. On the other hand, if the combination of measurements upon a new card does not coincide with any in the classed collection in the bureau, it is known with absolute certainty that the individual being dealt with has never been measured before.

One of the most striking results of the introduction of this system into France has been that, since it has been brought fully into operation, a large proportion of old offenders, knowing that concealment is hopeless, admit their identity at once, and save a world of trouble and expense to the police by ceasing to endeavour to conceal themselves under false names.

Various representations upon this subject have been addressed to the Home Secretary of our own Government during the last few years, and among others one from the Council of this Association, which originated in a resolution of this Section, adopted by the General Committee at the meeting at Edinburgh in 1892, to this effect:

'That the Council be requested to draw the attention of Her Majesty's Government to the Anthropometric Method for the measurement of criminals, which is successfully in operation in France, Austria, and other Continental countries, and which has been found effective in the identification of habitual criminals, and consequently in the prevention and repression of crime.'

In consequence of these representations a Committee was appointed, on Oct. 21, 1893, by Mr. Asquith, consisting of Mr. C. E. Troup, of the Home Office, Major Arthur Griffiths, Inspector of Prisons, and Mr. Melville Leslie Macnaghten, Chief Constable in the Metropolitan Police Force, with Mr. H. B. Simpson, of the Home Office, as secretary, 'to inquire (*a*) into the method of registering and identifying habitual criminals now in use in England; (*b*) into the "Anthropometric" system of classified registration and identification in use in France and other countries; (*c*) into the suggested system of identification by means of a record of finger marks: to report whether the anthropometric system or the finger-mark system can with advantage be adopted in England either in substitution for or to supplement the existing methods; and, if so, what arrangements should be adopted for putting them into practice, and what rules should be made under Section 8 of the Penal Servitude Act, 1891, for the photographing and measuring of prisoners.'

The Report of this Committee, with minutes of evidence and appendices, was issued as a Parliamentary Blue-book in March last, and not only contains a lucid and concise description of the methods of identification already in use in this country, but also most striking testimony from impartial but well-qualified persons to the value of a more scientific mode of dealing with the subject. No pains seem to have been spared to obtain, both by personal observation and by the examination of competent witnesses, a thorough knowledge of the advantages of the Bertillon system as practised in France, and the result has been the recommendation of that system, with certain modifications, for adoption in this country, with the addition of the remarkably simple, ingenious, and certain method of personal identification first used in India by Sir William Herschel, but fully elaborated in this country by Mr. Francis Galton, that called the 'finger-mark system,' about which I shall have a few more words to say presently.

With the concluding words of the Committee's Report I most fully concur: 'We may confidently anticipate that, if fairly tried, it will show very satisfactory results within a few years in the metropolis; but the success of its application in the country generally will depend on the voluntary co-operation of the independent county and borough police forces. This, we feel sure, will not be withheld. When the principles of the system are understood and its usefulness appreciated we believe it will not only save much time and labour to the police in the performance of an important duty, but will give them material assistance in tracing and detecting the antecedents of the guilty, and will afford, so far as its scope extends, an absolute safeguard to the innocent.'

It is very satisfactory to be able to add that in the House of Commons on June 26, in answer to a question from Colonel Howard Vincent, the Home Secretary announced that the recommendations of the Committee had been adopted; and that, in order to facilitate research into the judicial antecedents of international criminals, the registers of measurements would be kept on the same plan as that adopted with such success in France, and also in other Continental countries.

I have just mentioned the 'finger-mark system,' and of all the various developments of Anthropology in recent times none appears to me more interesting than the work done by Mr. Galton upon this subject; for though, as indicated above, he is not quite the first who has looked into the question or shown its practical application in personal identification, he has carried his work upon it far beyond that of any of his predecessors, both in its practical application and into regions of speculation unthought of by anyone else. Simple and insignificant as in the eyes of all the world are the little ridges and furrows which mark the skin of the under-surface of our fingers, existing in every man, woman, and child born into the world, they have been practically unnoticed by everyone until Mr. Galton has shown, by a detailed and persevering study of their peculiarities, that they are full of significance, and amply repay the pains and time spent upon their study. It is not to be supposed that all the knowledge that may be obtained from a minute examination of them is yet by any means exhausted, but they have already given important data for the study of such subjects as variation unaffected by natural or any other known form of selection, and the difficult problems of heredity, in addition to their being one of the most valuable means hitherto discovered of fixing personal identity.

As an example of the importance of some ready method to prove identity, apart from its application to the detection, punishment, and prevention of crime, to which I have already referred, I may recall to your recollection that remarkable trial which agitated the length and breadth of the land rather more than twenty years ago; a trial which occupied so many months of the precious time of our most eminent judges and counsel, and cost the country, as well as several innocent persons—I am afraid to say how many—thousands of pounds, all upon an issue which might have been settled in two minutes if Roger Tichborne, before starting on his voyage, had but taken the trouble to imprint his thumb upon a piece of blackened paper. It is wonderful to me, on reading again the reports of the trial, to see how comparatively little attention was paid by counsel, judge, or jury, to the extremely different physical characteristics of the two persons claimed to be identical, but which were so strongly marked that they ought to have disposed of the claim, without any hesitation, at the very opening of the case. It was not until the 102nd day of the first trial that the attention of the jury was pointedly called to the fact that it was known that Sir Roger Tichborne had been tattooed on the left arm with a cross, anchor, and a heart, and that the Claimant exhibited no such marks. When this was clearly brought out and proved, the case broke down at once. The second trial for perjury occupied the court 188 days, the Lord Chief Justice's charge alone lasting eight days. The issues were, however, more complex than in the first trial, as it was not only necessary to prove that the Claimant was not Tichborne, but also to show that he was someone else. I feel convinced that at the present time the greater confidence that is reposed in the methods of Anthropometry or close observance of physical characters, and in the persistence of such characters through life, would have greatly simplified the whole case; and I would strongly recommend all who have nothing about their lives they think it expedient to conceal to place themselves under the hands of Mr. Galton, or one of his now numerous disciples, and get an accurate and unimpeachable register of all those characteristics which will make loss of identity at any future period a sheer impossibility.

Partly with this object in view the Association has, for several years past, during each of its meetings, opened, under the superintendence of Dr. Garson, an Anthropometric Laboratory, on the plan of the admirable institution of the same name which has been carried on in the South Kensington Museum since the beginning of the year 1888, under the direction and at the sole cost of Mr. Francis Galton, in which up to the present time more than 7,000 complete sets of measurements have been made and recorded. The results obtained at the British Association meetings have been published in the Annual Reports of the Association, and, though on a smaller scale than Mr. Galton's, the operations of the laboratory have been most useful in diffusing a knowledge of the value of anthropometric work, and of the methods by which it is carried on.

For many years an 'Anthropometric' Committee of the Association, in which the late Dr. W. Farr, Mr. F. Galton, Mr. C. Roberts, Dr. Beddoe, Sir Rawson Rawson, and others, took an active part, was engaged in collecting statistical information relating to the physical characters, including stature, weight, chest-girth, colour of eyes and hair, strength of arms, &c., of the inhabitants of the British Isles; and their reports, illustrated by maps and diagrams, were published in the annual volume issued by the Association. This Committee terminated its labours in 1883, although, as was fully acknowledged in the concluding report, the subject was by no means completely exhausted.

A great and important work which the Association has now in hand, in some sense a continuation of that of the Anthropometric Committee, though with a more extended scope of operation, is the organisation of a complete ethnographical survey of the United Kingdom based upon scientific principles. In this work the Association has the co-operation of the Society of Antiquaries of London, the Folk-lore Society, the Dialect Society, and the Anthropological Institute. Representatives of these different bodies have been formed into a Committee, of which Mr. E. W. Brabrook is now chairman. It is proposed to record in a systematic and uniform character for certain typical villages and the neighbouring districts—(1) the Physical Types of the Inhabitants, (2) their current Traditions and Beliefs, (3) Peculiarities of Dialect, (4) Monumental and other Remains of Ancient Culture, and (5) Historical Evidence as to Continuity of Race. The numerous Corresponding Societies of the Association scattered over various parts of the country have been invited to co-operate, and the greater number of them have cordially responded, and special local committees have been formed in many places to carry out the work.

The result of a preliminary inquiry as to the places in the United Kingdom which appeared especially to deserve ethnographic study, mainly on account of the stationary nature of the population for many generations back, was given in the first Report of the Committee presented at the Nottingham meeting of the Association last year, in which it was shown that in the British Isles there are more than 250 places which, in the opinion of competent authorities, would be suitable for ethnographic survey, and in which, notwithstanding the rapid changes which have taken place during the last fifty years in all parts of the country, much valuable material remains for the Committee to work upon. Without doubt, as interest in the subject is aroused, this number will be greatly increased.

A most important step in securing the essential condition that the information obtained should be of the nature really required for the purpose, and that the records of different observers should be as far as possible of equal value and comparable one with another, has been the compilation of a very elaborate and carefully prepared schedule of questions and directions for distribution among those who have signified their willingness to assist, and as a guarantee that the answers obtained to the questions in the schedules will be utilised to the fullest extent, certain members of the Committee specially qualified for each branch of the work have undertaken to examine and digest the reports when received.

It may be remarked in passing that the Anthropological Society of Paris has within the past year formed a Commission of its members to collect in a systematic manner the scattered data which, when united and digested, shall form 'une anthropologie véritablement nationale de la France,' and has issued a circular with schedules of the required observations. These are, however, at present limited to the physical characters of the population.

Among the many services rendered to the science of Anthropology by the British Association, not the least has been the aid it has afforded in the publication of that most useful little manual entitled 'Notes and Queries on Anthropology,' of which the first edition was brought out exactly twenty years ago (1874), under the supervision and partly at the expense of General Pitt-Rivers. Since that time the subject has made such great advances that a second edition, brought up to the requirements of the present time, was urgently called for. A Committee of the British Association, appointed to consider and report upon the best means of doing this, recommended that the work should be placed in the hands of the Anthropological Institute of Great Britain and Ireland. This recommendation was approved by the Association, and grants amounting to 70*l.* were made to assist in defraying the cost of publication. The Council of the Anthropological Institute appointed a Committee of its members to undertake the revision of the different subjects, with Dr. J. G. Garson and Mr. C. H. Read as editors respectively of the two parts into which it is divided. The work was published at the end of the year 1892, and is invaluable to the traveller or investigator in pointing out the most important subjects of inquiry, and in directing the observations he may have the means of making into a methodical and systematic channel.

Besides those I have already mentioned, the Association has aided many other anthropological investigations by the appointment of Committees to carry them out, and in some cases by the more substantial method of giving grants from its funds, and by defraying the cost of publication of the results in its journal. Among these I may specially mention the series of very valuable Reports upon the Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada, drawn up by Mr. Horatio Hale, Dr. F. Boas, and others, the importance of which has been recognised by the Canadian Government in the form of a grant in aid of the expenses.

Another very interesting investigation into the Habits, Customs, Physical Characteristics, and Religion of the Natives of Northern India, initiated by Mr. H. H. Risley, and carried on under his supervision by the Indian Government, though it has received little more than moral support from the Association, may be mentioned here on account of the illustration it affords of the value of exact anthropometric methods in distinguishing groups of men. Although a practised eye can frequently tell at a glance the tribe or caste of a man brought before it for the first time, the special characters upon which the opinion is based have only lately been reduced to any definite and easily comparable method of description. In Mr. Risley's examination, the nose, for instance (which I have always held to be one of the most important of features for classificatory purposes), instead of being vaguely described as broad or narrow, is accurately measured, and the proportion of the greatest width to the length (from above downwards), or the 'nasal index,' as it is termed (though it must not be confounded with the nasal index as defined by Broca upon the skull), gives a figure by which the main elements of the composition of this feature in any individual may be accurately described. The average or mean nasal indices of a large number of individuals of any race, tribe, or caste offer means of comparison which bring out most interesting results. By this character alone the Dravidian tribes of India are easily separated from the Aryan. 'Even more striking is the curiously close correspondence between the gradations of racial type indicated by the nasal index and certain of the social data ascertained by independent inquiry. If we take a series of castes in Bengal, Behar, or the North-Western Provinces, and arrange them in the order of the average nasal index, so that the caste with the finest nose shall be at the top, and that with the coarsest at the bottom of the list, it will be found that this order substantially corresponds with the accepted order of social precedence. The casteless tribes—Kols, Korwas, Mundas, and the like—who have not yet entered the Brahmanical system, occupy the lowest place in both series. Then come the vermin-eating Musuhars and the leather-dressing Chamárs. The fisher castes of Bauri, Bind, and Kewat are a trifle higher in the scale; the pastoral Goala, the cultivating Kurmi, and a group of cognate castes—from whose hands a Brahman may take water—follow in due order; and from them we pass to the trading Khatris, the landholding Bábhans, and the upper crust of Hindu society. Thus, it is scarcely a paradox to lay down as a law of the caste organisation in Eastern India that a man's social status varies in inverse ratio to the width of his nose.' The results already obtained by this method of observation have been so important and interesting that it is greatly to be hoped that the inquiry may be extended throughout the remainder of our Indian Empire.

But for want of time I might here refer to the valuable work done in relation to the natives of the Andaman Islands, a race in many respects of most exceptional interest, first by Mr. E. H. Man, and more recently by Mr. M. V. Portman, and for the same reason can scarcely glance at the great progress that is being made in anthropological research in other countries than our own. The numerous workers on this subject in the United States of America are, with great assistance from the Government, very properly devoting themselves to exploring, collecting, and publishing, in a systematic and exhaustive manner, every fact that can still be discovered relating to the history, language, and characters of the aboriginal population of their own land. They have in this a clear duty set before them, and they are doing it in splendid style. I wish we could say that the same has been done with all the native populations in various parts of the world which have been, to use a current phrase, 'disestablished and disendowed' by our own countrymen. We are, however, now, as I have shown, not altogether unmindful of what is our duty to posterity in this respect; a duty, perhaps, more urgent than that of any other branch of scientific investigation, as it will not wait. It must be done, if ever, before the rapid spread of civilised man all over the world, one of the most remarkable characteristics of the age in which we live, has obliterated what still remains of the original customs, arts, and beliefs of primitive races; if, indeed, it has not succeeded—as it too often does—in obliterating the races themselves.

The following Reports and Papers were read:—

1. *The Report of the Anthropometric Laboratory Committee.*

See Reports, p. 444.

2. *The Report of the Ethnographical Survey Committee.*

See Reports, p. 419.

3. *The Report of the Committee on Anthropometry in Schools.*

See Reports, p. 439.

4. *On the Diffusion of Mythical Beliefs as Evidence in the History of Culture. By* EDWARD B. TYLOR, *D.C.L., LL.D., F.R.S.*

The purpose of this communication was to illustrate and systematise the use of correspondence in culture as means of tracing lines of connection and intercourse between ancient and remote peoples. Mythical beliefs are especially referred to as furnishing good evidence of this class, notwithstanding their want of objective value. The conception of weighing in a spiritual balance in the judgment of the dead, which makes its earliest appearance in the Egyptian religion, was traced thence into a series of variants, serving to draw lines of intercourse through the Vedic and Zoroastrian religions, extending from Eastern Buddhism to Western Christendom. The associated doctrine of the Bridge of the Dead, which separates the good, who pass over, from the wicked, who fall into the abyss, appears first in ancient Persian religion, reaching in like manner to the extremities of Asia and Europe. By these mythical beliefs historical ties are practically constituted, connecting the great religions of the world, and serving as lines along which their interdependence is to be followed out. Evidence of the same kind was brought forward in support of the theory, not sufficiently recognised by writers on culture history, of the Asiatic influences under which the pre-Columbian culture of America took shape. In the religion of old Mexico four great scenes in the journey of the soul in the land of the dead are mentioned by early Spanish writers after the conquest, and are depicted in a group in the Aztec picture-writing known as the Vatican Codex. The four scenes are, first, the crossing of the river; second, the fearful passage of the soul between the two mountains which clash together; third, the soul's climbing up the mountain set with sharp obsidian knives; fourth, the dangers of the wind carrying such knives on its blast. The Mexican pictures of these four scenes were compared with more or less closely corresponding pictures representing scenes from the Buddhist hells or purgatories as depicted on Japanese temple scrolls. Here, first, the river of death is shown, where the souls wade across; second, the souls have to pass between two huge iron mountains, which are pushed together by two demons; third, the guilty souls climb the mountain of knives, whose blades cut their hands and feet; fourth, fierce blasts of wind drive against their lacerated forms, the blades of knives flying through the air. It was argued that the appearance of analogues so close and complex of Buddhist ideas in Mexico constituted a correspondence of so high an order as to preclude any explanation except direct transmission from one religion to another. The writer, referring also to Humboldt's argument from the calendars and mythic catastrophes in Mexico and Asia, and to the correspondence in Bronze Age work and in games in both regions, expressed the opinion that on these cumulative proofs anthropologists might well feel justified in treating the nations of America as having reached their level of culture under Asiatic influence.

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5. *On Complexional Differences between Natives of Ireland with Indigenous and Exotic Surnames respectively.* *By* JOHN BEDDOE, *M.D., LL.D., F.R.S.*

Taking his data chiefly from the military reports, the author shows that while the former class of Irishmen are largely characterised by the prevalence of light eyes and dark hair, in the latter dark hair is much less frequent. He suggests that a simple mixture of Englishmen, Scotchmen, &c., with the natives should have also decidedly increased the proportion of dark eyes, which has not been the case to any considerable extent; and that the influence of climate, which, if operative at all, should tell in favour of the blonde complexion, may have had some effect upon an unstable cross-breed.

Eyes . .	Light						Dark					
Hair . .	Red	Fair	Brown	Dark	Black	Totl	Red	Fair	Brown	Dark	Black	Totl.
Indigenous names .	3·5	20·6	26·4	19·3	4·5	74·3	1·3	2·9	7·9	10·2	3·1	25·4
Exotic names .	2·4	22·9	29·1	16·2	2·8	73·4	1·4	3·4	10·2	8·7	2·7	26·4

FRIDAY, AUGUST 10.

The following Reports and Papers were read:—

1. *The Report of the Committee on Prehistoric and Ancient Remains in Glamorganshire.*—See Reports, p. 418.

2. *The Report of the Committee on the Exploration of Elbolton Cave.* See Reports, p. 270.

3. *The Report of the Committee on the Explorations at Oldbury Hill.*

4. *On the Evolution of Stone Implements.* *By* H. STOPES.

The author defined an 'Implement' to be any stone used to facilitate man's actions, not necessarily made, but used; use being determined by wear. By 'Evolution' he meant a series of improvements in flint implements, the result of mental processes and widening experience, though points are reached in all developments, beyond which advance on the same lines stops.

The earliest tools were any chance natural stones used for breaking, bruising, or hammering. Traces of use are not perceived on these unless they were frequently used, when they became worn or polished. The next step was the selection of stones suitable for given purposes, and convenient to be held in the hand. The only signs these show of being implements are also marks of wear. The author showed many such specimens, and referred to the collection of Mr. Harrison, of Ightham. Natural stones were next gradually trimmed for use by a few strokes. These also were illustrated by a series of what the author termed 'transitional' forms, as they are intermediate between the *selected and used*, and the *worked and used*, or Palæolithic implements. The transitional stones are frequently large and rough, generally left-handed, and with thick patination. The terms Palæolithic and Neolithic have become indefinite. Many of the Palæoliths are evidently meant for handles, and some of them are of finer work than the Neoliths. Specimens were shown from many localities, but chiefly from the upper-level gravels of Kent, from 80 feet to 300 feet above the O.D., including anvils, hammers, anchors, net-weights, single- and double-pointed drills or borers, gyrators, axes, spokeshaves, fabricators and arrow-heads; and their parallels were shown from each period. These are the types of many of the steel tools of to-day. A set of sharp-pointed axes having a spiral twist were shown to be developed into the peculiar gyrators of the rock-shelter men, found also amongst the gravels of Swanscomb. Specially instructive are the natural but used stones. Fully half of these show no bulb of percussion. These invaluable records are fast disappearing from free use for concrete and road metal. The importance of preserving worked stones for the use of future students, and the value to the critic of being able to compare a large series together, in order to form just conclusions, were pointed out.

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5. *A Joint Discussion with* Section C *on the Plateau Flint Implements of North Kent was held, for which see p.* 651.

SATURDAY, AUGUST 11.

The following Reports and Papers were read:—

1. *The Report of the Committee on the Mental and Physical Condition of Children.*—See Reports, p. 434.

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2. *On a New System of Hieroglyphics and a Præ-Phœnician Script from Crete and the Peloponnese.* *By* ARTHUR J. EVANS, *M.A.*

The author said that the Mycenæan civilisation was in many respects the equal contemporary of those of Egypt and Babylonia, and they might well ask themselves, Was this civilisation wholly dumb? Homer, at least, contained a hint that some form of written symbols was in use.

During a journey to Greece in the preceding year Mr. Evans had obtained a clue to the existence of a peculiar kind of seal-stones—the chief find-spot of which seemed to be Crete—presenting symbols of a hieroglyphic nature. This spring he had been able to follow up his inquiries by the exploration of the ancient sites of Central and Eastern Crete, and the result of his researches had been to bring to light a series of stones presenting pictographic symbols of the same nature, so that he was now able to put together over seventy symbols belonging to an independent hieroglyphic system. More than this, he had discovered, partly on stones of similar form, partly engraved on prehistoric vases and other materials, a series of linear characters, a certain proportion of which seemed to grow out of the pictorial forms. Both these systems of writing were represented as the diagrams exhibited. It would be seen that, as in the case of the Egyptian and Hittite symbols, the Cretan hieroglyphs fell into certain distinct classes, such as parts of the human body, arms and implements, animal and vegetable forms, objects relating to maritime life, astronomical and geometrical symbols. Some of them, such as the two crossed arms with expanded palms, belonged to that interesting class of pictographs which is rooted in primitive gesture language. The symbols occurred in groups, and there were traces of a *boustrophedon* arrangement in the several lines. The comparisons instituted showed some interesting affinities to Hittite forms. Among the tools represented, Mr. Evans was able to recognise the 'template' or 'templet' of a decorative artist, and, with the assistance of a model of this symbol taken in connection with a design supplied by a Mycenæan gem found in Crete, he was able to reconstruct a Mycenæan painted ceiling analogous to those of Orchomenos and the eighteenth-dynasty Egyptian tombs of Thebes (*circa* 1600 B.C.).

The linear and more alphabetic series of symbols was shown to fit on to certain signs engraved on the walls of what was apparently a Mycenæan palace at Knôsos, and again to two groups of signs on vase-handles from Mycenæ. It was thus possible to reconstruct a Mycenæan script of some twenty-four characters, each probably having a syllabic value. It further appeared that a large proportion of these were practically identical with the syllabic signs that survived among the Greeks of Cyprus to a comparatively late date. The Cypriote system threw a light on the phonetic value of the Mycenæan.

Resuming the results arrived at, Mr. Evans said that they had now before them two systems of primitive script—one pictographic, the other linear—both, as was shown by the collateral archæological evidence, belonging to the second millennium before our era, and to the days before the Phœnician alphabet had been introduced among the Greeks. Some pictorial forms, however, of the one series clearly appeared in a linear form in the other; the double axe, for instance, being seen in two stages of linearisation—the simpler form identical with the Cypriote character. On the whole, the pictographic or hieroglyphic series seemed more peculiarly indigenous to Crete, and the linear forms to be Mycenæan in the widest sense. The Eteocretans, or indigenous stock of the island, who preserved their language and nationality in the east of the island to the borders of the historic period, certainly used these hieroglyphs. Mr. Evans gave reasons, based on his recent archæological discoveries in Eastern Crete, for believing—what had long been suspected on historic and linguistic grounds—that the Philistines who, according to unanimous Hebrew traditions, came from the Mediterranean islands, and who are often actually called *Krethi* in the Bible, represented in fact this old indigenous Cretan stock; and that they had here the relics and the writing of 'the Philistines at home.' On Egyptian monuments a people, who came from 'the islands of the sea,' are seen bearing tributary vases of forms, some of which recur on a whole series of engraved gems seen or collected by Mr. Evans in Eastern and Central Crete. Their dress, their peaked shoes, their long hair falling under their arms, all recurred on Cretan designs, representing the inhabitants of the island in Mycenæan times.

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3. *Exhibition of Prehistoric Objects collected during a Journey and Explorations in Central and Eastern Crete. By* ARTHUR J. EVANS, *M.A.*

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4. *The Heredity of Acquired Characters.*
By Professor A. MACALISTER, *M.D.*, *F.R.S.*

5. *Notes on Skin, Hair, and Pigment.*
By Professor ARTHUR THOMSON, *M.A.*

6. *On the Anthropological Significance of Ticklishness.*
By LOUIS ROBINSON, *M.D.*

The ticklishness which is so marked in children, and which is associated with laughter, appears to be different from the ticklishness of the surface of the skin.

Its universal distribution indicates that it was at one time of importance, although at present it appears to fill no place in the animal economy.

It is found that in young apes, puppies, and other like animals, the most ticklish regions correspond to the most vulnerable spots in a fight. In the mock fights of immaturity, skill in defending these spots is attained.

In children, and in anthropoid apes which fight with their canine teeth, the most ticklish regions are practically identical. Young orangs and chimpanzees grin, and behave otherwise much like children when tickled.

It seems probable, therefore, that in the ticklishness of children we have a vestige of a state of racial development when the canine teeth were habitually used by our ancestors in war for mates or food.

7. *On the Bow as a Musical Instrument.* *By* H. BALFOUR, *M.A.*

The bow has been for a long while commonly accepted as the prototype of a large series of stringed musical instruments. Witness the Greek legend which attributed the first appreciation of the musical potentialities of a tense string to Apollo, who observed them in the twang of the bowstring. In India legend refers the invention of stringed instruments to Siva, who used a bow for musical purposes. In Japan the origin of the six-stringed koto is, in the legend of Amaterasu, traced to an extemporised instrument composed of six bows lashed together. So, too, modern writers have for the most part regarded the bow as a parent form of many of the instruments even of the highest types. Stages in the probable phylogenetic development of stringed instruments may be studied in the *survivals* of primitive forms still existing in various countries. Simplest of all is the monochord of the Damaras (Herero), extemporised from the ordinary shooting bow of the country by the addition of a string bracing the bowstring to the bow, and thus tightening it and dividing it into two parts, whose notes are elicited by tapping upon the string with a small stick. To increase the resonance the bow is held to the mouth of the performer. Stage 2 is represented in many parts of Africa by musical bows, still simple bows, very slightly modified for musical purposes only. These are either held in the teeth or to the mouth, or rested upon resonant bodies (gourds, &c.) to increase resonance. Stage 3 is that in which a resonator is *attached* to the bow, usually a gourd, as in the Zulu 'gubo.' Musical bows in these three stages occur from the Niger down the west of Africa to the Cape, and along the more easterly regions as far north as the Dohr or Bongo tribes. This distribution is nearly continuous. In Asia we meet at the present day with musical bows in forms corresponding with stage 2, as in the Pināka of North India, a lightly made bow strung with fine string. Also the musical bow of the Bhuiyars (aboriginal) of Mirzapur, though this is an aberrant form. It seems likely that a musical bow almost identical with the bow and gourd resonator of South Africa exists in India, this observation being partly based upon a small figure of a man with such a bow in the Pitt-Rivers collection, and partly upon a study of forms which seem to have passed through such a stage. In the Malay regions we find musical bows used with or without resonators in the 'busoi' of Borneo, and in a simple form in

Timor. Eastwards a variety occurs in the 'pangolo' of New Britain, a bow with two strings, one of which is braced to the bow with a string, as in South African examples. In the Solomon Islands miniature bows are played upon with the fingers; at least three varieties are known there, one of which has two strings ('kalove' of Florida Island). In the Marquesas group a musical bow exists; and in the Sandwich Islands an instrument is found which, though it can hardly be called a 'bow,' is evidently closely allied to the two-stringed 'kalove' of Florida Island. In the New World a pretty wide range is seen for the musical bow, but as it is here evidently of African origin, and owes its transmission to the immigration of African labour, the instrument in this region calls for no special remark.

In Africa one may still trace stages in the development of the primitive forms of harps from the musical bow, while the more elaborate harps of the ancient Egyptians and Greeks show unmistakable signs of this original derivation, as does the modern harp of Burma, and that of the Ossetes of the Caucasus, as also several harp-like forms of mediæval times in Western Europe. These all agree in the absence of a supporting front pillar, and the many obvious inconveniences of these forms justify one in saying that these instruments would never have come into existence except as a gradual development from primitive bow-like forms, the awkwardness of whose structure persisted through a somewhat blind adherence to traditional form. In India there is evidence that the 'vina' owes its origin to the bow, there still surviving various intermediate types which can reasonably be regarded as survivals of various stages in the phylogeny of the group.

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8. *The Relations between Body and Mind, as expressed in Early Languages, Customs, and Myths. By* Rev. G. Hartwell Jones, *M.A.*

The conditions in which early races lived precluded the possibility of arriving at anything like anatomy or psychology. Yet some crude notions appear in ancient literatures, customs, and myths, and these become more intelligible when viewed in the light of similar superstitions which have prevailed at all times among unprogressive tribes of savages. Naturally, the study of the physical frame and mental constitution received but little attention before the rise of science in the East and Asia Minor.

That the Indo-European *Urvolk* must have had some knowledge of (i.) *the body* is proved by their common inheritance of descriptive *words* for parts of the human frame. Even where the roots of vocables relating to the body are not akin, there is a resemblance in the *conceptions* prevalent in widely distant parts of Europe, and, indeed, of the globe. Among their common possessions are (1) *words*, some describing the creation of the body, others the shape, others the substance. Again, (2) the similarity of the *conceptions* is noteworthy. When analysed, these exhibit a growth of meaning, transition of thought, and gradual gain in distinctness of idea. At first, however, there is constant confusion. Thus the bodily sense is confused with its organ, and a connection was supposed to exist between defects of the body and mental weakness. The habit also of employing one member to represent the whole is frequently found in early stages of language, and particularly in poetry. And if the ideas concerning the body and its parts were indistinct, as was to be expected in the earlier stages of human development, still more vague was the knowledge of (ii.) *the mind* and its phenomena. Especially common among primitive and backward races is the notion that life, mind, and soul are air, vapour, or shade; for example, in Sanskrit, Greek, Latin, and Teutonic languages. Their general idea, too, of the mental faculties was hazy. Even as late as Homer's age the body was regarded as the source of all actions, but by the poet's time knowledge had progressed far enough to discriminate the intellectual and emotional faculties, the power of reflection, memory, and imagination. In this connection several interesting points arise: (α) in the growth of language and thought the physical and concrete precede the psychical and abstract; for instance, in Greek, Latin, Persian, Sanskrit, and Chinese. (β) There was until a very late period still some confusion between the functions of the different parts of the body, or between the functions of the blood in relation to those of body and mind. Equally loose are the notions respecting (iii.) bodily and mental *disease*. At first the diseased were put to death, and when the healing art originated, diseases were attributed to divine or demoniacal agency. Such was the case even with the Assyrians, Babylonians, and Greeks. This being the case, supernatural remedies were sought, and although by Homer's day human methods were employed, yet traces of the Divine influence are distinctly discernible. This is seen in the propitiation of evil spirits, such as Nosos, Febris, Apollo, Artemis; in the superstitious reverence with which epilepsy and madness were regarded, together with many other superstitions of which glimpses appear as late as Plato. Especially instructive is the worship of Æsculapius, the patron of medicine, whose history, stripped of the legendary lore that has gathered around him, reveals an historical personage. His traditional descent from the Sun-God, his initiation by the Thessalian Centaur, the combination of incantations and prayers, with human aids, like embrocations, salves, potions, and the knife, the peculiar custom of *κατακοιμᾶσθαι*, and the important part played by the serpent and the cock in his worship, exhibit a strange mixture of the natural and supernatural, and well illustrate the early evolution of the art of medicine.

An examination of the growth of knowledge of the body and mind, and their treatment, therefore affords further proof that (1) the primitive condition of the pioneers of civilisation was no higher than that of savages; (2) the parallels presented by words and ideas in countries widely separated from one another cannot be satisfactorily explained by coincidence; (3) the civilisation of Western Europe, viewed as a whole, began in contact with the East.

9. *On the Alleged Presence of Negritoes in Borneo.*
By H. Ling Roth.

The circumstantial evidence collected by the late Mr. Earl that a people of a negroid character existed in Borneo, and the discovery by M. Hamy of a negrito skull from that island, has led to the established belief that negritoes exist there. The skull in question undoubtedly came from Borneo, and it is undoubtedly a negrito skull; but there is no proof that it originated in Borneo. We know that Andaman Islanders (negritoes) have been kidnapped by Malay and Ilanum pirates and carried to India and other parts, so that for the present, in spite of the strong circumstantial evidence, we must withhold our judgment as to whether negritoes exist in Borneo.

10. *On the Possibility of a Common Language between Man and other Animals.* *By* Miss Agnes G. Weld.

The authoress pointed out that the Hebrews, Greeks, and Romans believed that at one time man and animals could understand each other's languages, whilst at the present day an Irish peasant will tell you that the cock, on Easter morning, crows in good Erse the tidings that the Lord is risen. In these old and popular legends most stress is laid on the acquisition of human speech by animals, whereas modern scientific effort is tending in the reverse direction. She believes that, with the exception of the parrot and one or two other birds, the creatures below us in the scale of existence are unable to pronounce the full gamut of sounds we can utter, some making use of vowels alone, others merely of consonants, so that it is far easier for us to speak in their language than for them to talk in ours. Miss Weld proceeded to exemplify this by telling of a daily conversation she used to hold with a wild nightingale, and then narrated the remarkable effect produced by her upon a savage retriever that had set upon a collie. Miss Weld described how, when she had growled out certain deep notes of dog language, an awestruck expression came into the retriever's eyes; and how, instantly letting go his hold of the collie, he answered the deep notes by a whispered growl, backing as he did so into a corner, where he remained, in the most abject terror, not venturing to stir till Miss Weld was out of sight.

11. *On Mythical Pygmy Races.*
By Professor Bertram Windle, *D.Sc.*, *M.D.*

In this communication it was shown that the idea of mythical pygmy peoples, fairies, or elves, was diffused throughout the world; that whilst general features of resemblance were present, there were many points of distinction, and notably with regard to the nature of their supposed dwelling-places, an account of which was given.

An attempt was made to show that no single explanation is adequate to account for these legendary races, but that a number of elements enter into the composition of the myth.

MONDAY, AUGUST 13.

The following Reports and Papers were read:—

1. *Pygmies in Europe.* *By* Professor J. Kollmann, *M.D.*

Near Schaffhausen, in Switzerland, a prehistoric settlement was described by the author which had been used successively in Palæolithic, Neolithic, and Metallic times. Each period was distinctly separated from the other by a differently coloured stratum. The Palæolithic stratum contained a large number of the broken bones of reindeer, also those of horse, ice-fox, bear, and other animals in less number. No human bones were found in it, only worked flakes. It was covered over by a layer of breccia, 80 cm. thick, which contained no traces of man.

Over this came the Neolithic stratum, of an average thickness of 40 cm., which contained potsherds and large quantities of ashes, giving it a grey tinge. The animal remains found in it were those of stag, roe, black bear, ox, &c.; the reindeer had entirely disappeared. The uppermost stratum is a layer of humus 40 to 50 cm. thick. During its formation man had ceased to settle there for any length of time under the shelter of the overhanging rocks. A few implements were found in it, but they were of an inferior kind, so that this layer of the so-called Metallic period calls for no further comment. Not so with the Neolithic stratum, in which were more than twenty human interments, both of adults and children. Eleven of the latter varied in age from the new-born child up to that of seven years, and some of them were buried with particular care. The adult interments consisted of the skeletal remains of (*a*) full-grown European types, and (*b*) small-sized people, which must be considered as pygmies of the Neolithic period of Europe. These two races were found interred side by side under precisely similar conditions; from which it may be concluded that they lived peacefully together, notwithstanding their great racial difference. The remains of four of these pygmies, and probably of a fifth, were found. Their stature, estimated according to Manouvrier's method, from the femur, is as follows:—No. 2, 1,416 mm.; No. 12, 1,355 mm., and No. 14, 1,500 mm., giving an average of 1,424 mm. This may be compared with the average stature of the Veddas of Ceylon, which is 1,576 mm., according to Sarasin, and with the skeleton of an Andaman Islander measured by the author, in which the femur measured 424 mm., the stature of the skeleton being 1,500 mm., while the femora of the Swiss Neolithic pygmies are: No. 2, 369 mm.; No. 12, 355 mm., and No. 14, 393 mm.

There were seven interments of the taller race, of which the femur of No. 5 measured 454 mm., giving a stature of 1,662 mm., which Rollet found to be the average height of adult Frenchmen. The remains of the other individuals of this race could not be satisfactorily measured.

The author stated, on the authority of Professor Virchow, that the bones of the small race are not those of a pathologically degenerated people, but of normal structure. In connection with this find it is important to note that Sergi and Mantia have discovered some living pygmies in Sicily and Sardinia, mostly under 1,506 mm. in height in Sicily. In appearance they look like miniature Europeans. In the author's opinion these small types must be regarded, not as diminutive examples of normal races, but as a distinct species of mankind which occurs in several types dispersed over the globe; and he is led to believe that they have been the precursors of the larger types of man.

2. *On some Stone Implements of Australian Type from Tasmania.*
By E. B. Tylor, *D.C.L., F.R.S.*

The ordinary stone implements used by the Tasmanians were remarkable for their rudeness. They come generally under the definition of substantial flakes, trimmed and edged by chipping on one side only, not ground even at the edge, and grasped in the hand without any kind of handle. The Palæolithic level of these implements, notwithstanding their often recent date, had been pointed out by the writer.[1] In illustration of this comparison, Tasmanian implements were now exhibited side by side with flint implements from the cavern of Le Moustier, in Dordogne. But an important point of exception as to this comparison, mentioned in the paper referred to, demands reconsideration in view of the new evidence now brought forward. In the investigation as to native stone implements conducted about twenty years ago by the Royal Society of Tasmania, some exceptional statements were made as to stone axes or 'tomahawks' being ground to an edge, and fixed in handles, and these were explained as due to the Australian natives who have passed into Tasmania since the European settlement. What was meant by these statements now appears more clearly from three ground implements of distinctly Australian character, well authenticated as brought from Tasmania, and now exhibited by the courtesy of the Municipality of Brighton, to whose museum they belong. The largest has a label showing that it was obtained through Dr. Joseph Milligan, probably from G. A. Robinson, the first protector of the aborigines after the native war; and that it was grasped in the hand for notching trees in climbing. The other two specimens are merely marked 'Tasmanian,' with the initials 'G. A. R.' The coexistence of two such different types as the chipped and ground forms in Tasmania requires, however, further explanation. This may probably be found in the immigration of Australians either after or before the English colonisation, but it would be desirable that anthropologists in Tasmania should make further inquiry into the question on the spot, so as fully to clear up the interesting position of the Tasmanian Stone Age.

3. *On Tasmanian Stone Implements.* *By* H. Ling Roth.

4. *The Troglodytes of the Bruniquel, a Grotto of Ironworks on the Borders of Aveyron.* *By* Dr. Emile Cartailhac.

The collection of which M. Emile Cartailhac showed photographs has been formed by the Viscomte de Lastic. It is the complement of the beautiful series acquired some time ago by the British Museum.

The engravings upon bone and the sculptures representing animals are very remarkable, and throw a bright light on the art of the Reindeer Age. Amongst the most interesting objects are the straight beams of reindeer horn, sculptured at one extremity in the form of a horse as seen from the front, head lowered against the breast, feet joined. There are several pieces of this kind, almost similar. Lartet found similar specimens, but broken and unrecognisable, in the layers of the

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[1] 'On the Tasmanians as Representatives of Palæolithic Man' in *Journ. Anthrop. Inst.*, vol. xxiii. 1893, p. 141.

Dordogne. Others have been described in the rock shelters of the Pyrenees and in Switzerland. M. Cartailhac laid stress on the conclusions which can be deduced from the presence of similar pieces in layers so remote. Of all the sculptured objects of the same epoch this is the only one which to any extent had a look of repetition.

M. Emile Cartailhac then entered into an exposition of the facts which led him to consider that neither the reindeer nor the horse was domesticated or bridled during the Reindeer Age.

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5. *A New Statuette of the Reindeer Age representing a Woman, Sculptured in Ivory.* *By* Dr. EMILE CARTAILHAC.

The rock shelters of Brassempouy, on the waste land north of the little village of Orthes, includes one of the richest layers of the Quaternary epoch. The mammoth and its contemporaneous fauna are largely represented; with flints, recalling to mind in some instances the types of Langerie Haute and of Solutré, lay a certain number of the worked bones and also remarkable pieces of sculpture, some of which have been described in 'Matérieux' and elsewhere; others are still unpublished.

Amongst the latter is a broken ivory statuette, collected by M. Dubalen, Conservateur of the Museum of Mont de Marsan, a portion of which M. Emile Cartailhac has reconstructed. The loss of the upper part of the bust in this specimen is very unfortunate, since, if one may judge by the rest of the body, it was carved with great regard to truth and exactitude. This human representation is the best made one which is known of the reindeer period. It proves once more the value of the artistic sentiment of these distant ages.

These engravings and prehistoric sculptures have frequently been compared to those of the primitive populations of North America and Asia, but the more these works multiply, the more they affirm the incomparable superiority of the troglodytes, our ancestors.

M. Emile Cartailhac exhibited the original specimen.

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6. *The End of the Stone Age on the Borders of the Mediterranean Basin.* *By* Dr. EMILE CARTAILHAC.

The author explained the analogies and identities proved to exist at the two extremities of the Mediterranean—in Egypt, at Troy, in Greece, and at Santorin at the one end, and in Spain at the other end.

The civilisation, which corresponds to the end of the Stone Age, appears to have special characters and a remarkable uniformity. It does not only influence the same objects, but especially the manners and customs, as shown by exhumed monuments, houses, small market towns, fortifications, and tombs.

Between the East and the Iberian Peninsula, transition is shown by the numerous discoveries in Italy, France, Algeria, Tunis, and the Islands. The connections of this primitive civilisation with the Stone Age of the rest of Europe are remarkable, and illustrate best the diversity of their origins.

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7. *On the Present State of Prehistoric Studies in Belgium.* *By* Count GOBLET D'ALVIELLA.

The author reviewed briefly the various investigations which have been made in Belgium regarding the early history of man in that country, beginning with the exploration of the caves, which have in recent years, as well as in earlier times, yielded such interesting results as to their occupation as far back as the period of the mammoth and the reindeer, and also in Neolithic times. He then proceeded to give an account of Quaternary finds in the plains, consisting of flint implements in all stages of manufacture, both of Palæolithic and Neolithic times. The manufacture of flint implements appeared to have been an important industry, extending all over Belgium.

The sites of Neolithic occupation are situated near streams, on the tops of hills, and promontories of high ground. Villages have been found consisting of symmetrically grouped huts excavated in the soil. They contain no trace of metals, only tools of polished flint and fragments of baked pottery made on the wheel, and with linear ornamentation.

Recent researches have shown the existence of Dolmen monuments, which was till lately denied. The existence of a real Bronze Age in Belgium has also been disputed, but finds of bronze articles in tumuli associated with incineration and burials are becoming more numerous.

The beginning of the Iron Age is undoubtedly represented in Belgium in various burial-grounds and tumuli, which have recently yielded new and fruitful researches.

8. *Observations on the Antiquity of Man in Belgium.*
By Professor MAX LOHEST.

9. *Exploration of British Camps and a Long Barrow near Rushmore.*
By General PITT-RIVERS, *F.R.S.*

10. *On a New Craniometer.* *By* General PITT-RIVERS, *F.R.S.*

11. *On the Long Barrow Skeletons from Rushmore.*
By J. G. GARSON, *M.D.*

12. *Report of the Committee on the Glastonbury Exploration.*
See Reports, p. 431.

13. *On Ancient Bone Skates.* *By* ROBERT MUNRO, *M.D.*

The author commenced by observing that the contradictory opinions enunciated by archæologists in regard to the period when bone skates were used justified this attempt to define their position in early European civilisation with greater precision than had hitherto been done. Bone skates had been found in large numbers in the *Terp*-mounds of Holland, and among the *débris* of the ancient town of Birka, on the island of Björkö, in Lake Mälar. Sporadic examples were to be seen in various museums throughout Northern Europe, said to have been found in grave-mounds, lake-dwellings, canal-diggings, &c. The late Dr. Lindenschmit promulgated the opinion that these objects belonged to the Stone Age, and this opinion had been subsequently adopted by various archæologists. In this paper Dr. Munro has collected and criticised the details of all the hitherto-recorded discoveries, and comes to the conclusion that there is no trustworthy evidence in support of the theory that bone skates were ever used in prehistoric times in Europe. According to the author, they would appear to have been invented by the early Teutonic races who inhabited the shores of the Baltic, and to have been introduced into Britain by the early immigrants, who hailed probably from among the superfluous inhabitants of the *Terpen*. This opinion is supported by their geographical distribution, which embraced Holland, Denmark, the lower portions of Scandinavia, North Germany, and a small district in England extending along its eastern shore, including York, Lincoln, and London.[1]

14. *On the People of Western Ireland and their Mode of Life.*
By Professor A. C. Haddon.

TUESDAY, AUGUST 14.

The following Papers were read:—

1. *On three Neolithic Settlements in North Kent.* *By* Mrs. Stopes.

Mrs. Stopes treated the topographical relations of the localities in which she has found the traces of Neolithic settlements in the neighbourhood of Swanscombe. They all face east. Is there any possible meaning in this? The shapes of the tools and flakes are very similar, though there must have been long intervals at least between two of them, as one tribe used the pebbles of the Woolwich and Reading beds, the other fresh chalk flints of a fine quality. Mrs. Stopes also noted the information to be gained regarding the chief settlement from the places in which the different types of worked flints are found. The flakes and chips show where the flint-workers worked; the warlike weapons mark the line of defence, &c.

2. *On the Native Tribes between the Zambezi and Uganda.*
By Lionel Decle.

After explaining the origin of the name of Mashona—an English corruption of the nickname of Amashuina (baboons) given by the Matabele to the Makalanga—Mr. Decle gave a sketch of the various tribes found between the Zambezi and Uganda, and criticised the classification of the native races according to their language. He explained how, for instance, some tribes classified as Bantu differed physically from others included under the same name. An account was given of the customs prevailing amongst the people between the Zambezi and Uganda. Mr. Decle showed a living specimen from the country he had visited—a young boy, whom he had brought back with him—and gave his history. The boy, who came from the west shore of Tanganyika, had been sold by his own brother to a coast man for two yards of calico. On the way to the coast he got sore-footed, and was sold to a Wahha chief for three goats. When Mr. Decle was in the Wahha country he was attacked every night, and at last, in order to put a stop to it, he one day caught a chief and threatened to hang him if his goods were not returned. After much talking Mr. Decle agreed to take as a ransom the child and ten goats. The boy, although he refused to return to the Wahha or to his own people, was for a long time afraid that Mr. Decle would eat him up.

3. *On the Lex Barbarorum of the Daghestan.*
By Professor Maxime Kovalevsky.

The author insisted on the necessity of more trustworthy information as to old customs and usages being obtained by travellers, and expressed a hope that English ethnographers in India would search for old collections of sentences pronounced by judges As an instance, he mentioned the existence of such a treatise in the Daghestan. It is preserved in Derbent, on the shores of the Caspian, and is known by the name of the Roustem Code. Olearius, a well-known traveller at the beginning of the seventeenth century, mentions his visit to Roustem, who was a kind of elected judge or arbitrator, called an 'outzmi.' His subjects were Tartars of the Kaitag, who had no writing of their own. The treatise is written in Arabic. It contains many very old customs and usages, and admits the vengeance of blood, which extends from the first to the last relatives inward to all the members of the tribe, called 'Touchoum.' Compositions are paid in rough linen called mabzaldick. Whoever wished to escape the obligations of mutual responsibility was obliged to declare solemnly that all ties were broken between him and the members of his tribe, and a nail was placed in the wall of the mosque in commemoration of it. The treatise of Roustem inflicts a high amercement on those who use it without the permission of the 'outzmi.' 'Who keeps his mouth will not lose his head,' is the common saying placed at the top of each sentence. It shows that the mediators in Daghestan, just like the Brehons of Ireland, kept their knowledge for themselves and their pupils.

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[1] This paper will appear *in extenso* in the *Proceedings of the Society of Antiquaries of Scotland*, 1893–94.

4. *On the Natives of the Hadramout.* *By* J. THEODORE BENT.

After referring to the ancient inhabitants and the archæology of this district, the country from which the ancient world obtained its frankincense and myrrh, Mr. Bent went on to describe the present inhabitants of the country and the extreme difficulties in the way of pursuing anthropological research in it. He divided the inhabitants as follows, into four divisions, and gave an account of each.

Firstly, the Bedouins, an obviously aboriginal race, with a religion of their own and mysticism at variance with the orthodox religion of the land. He considered them to be more like the Gallas in physique; and when proper measurements can be taken, in all probability an affinity will be established between these two races on either side of the Indian Ocean.

Secondly, the Arabs proper, who came from Yemen and conquered the country three centuries ago. He gave a description of their women and their customs and fanaticism, of the men who go to India in search of a livelihood, and of the Sultans of the Al Kaiti family.

Thirdly, the Sayyids, a sort of hierarchical nobility who fan the fanatical tendencies of the race and rule everything, both in religion and law; and to them is due the fact that the Hadramout has continued so long to be shut off from exploration and the rest of the world.

Fourthly, the slave element, which in this country is considerable. Mr. Bent described them as living a very happy life and subject to very few social disabilities.

5. *On the Shells used in the Domestic Economy of the Indonesians.*
By Dr. J. D. C. SCHMELTZ, *of Leiden.*

The author submitted a systematic list of no fewer than 154 shells used by the aborigines of Indonesia and Oceana in their domestic economy, and a table showing the geographical distribution of their use for different purposes. The author gave an account of the different modes of using shells. Some are much preferred to others, for a great variety of purposes. Shells are also used in connection with religious ceremonies. He concluded with some observations on the manner of making implements, ornaments, &c., from shells.

6. *On the Pantheon of the Fijians.* *By* BASIL H. THOMSON.

The author described the Fijian Olympus, the mountain of Nakauvadra. The tutelar deities of Fijians are the spirits of their dead ancestors. The growth of this idea may be traced in the development of the complete tribe from a single family, and the process may be tested by an examination of the bond of *tauvu*. Tribes that are *tauvu* (*i.e.*, sprung from the same root) worship the same gods.

The author described the legends of the arrival of the Fijians from the westward and the peopling of Nakauvadra; the story of Turukawa and the scattering of the tribes. These fragments of mythology are of historical value.

The recent discovery of the 'path of the spirits,' the legends that cling to it, showing the influence of physical geography on the mythology of the Fijian bogies and apparitions, were briefly described.

The author described the *Nanga* cults, the earliest example of missionary enterprise in the Pacific; the *arcana* of the Nanga and their meaning.

In conclusion he referred to the recent recrudescence of heathen practices and its political danger.

7. *The Distribution of the Picts in Britain, as indicated by Place-Names.*
By J. GRAY, *B.Sc.*

The *Picti* of North Britain, and the *Pictones* or *Pictavi* of South Gaul, are both mentioned by Roman writers. The evidence of place-names shows that probably the whole intervening country was at an earlier date occupied by the same race. Two roots are employed to determine the relative densities of the Picts in Britain—viz. *Pict* and its variants, and *Al*. The language of the Picts was Basque. The name Pict is derived from a Basque word, *pikatu*, to cut. Aquitania is probably a Goidelized form of Paquitania, or Pakitani, and meant in the Pictish language, the country of the Picts. *Pakat* is deduced as the earliest form of the name Pict. The different phonetic changes which *pakat* can undergo are indicated, and some of these are verified by historical evidence. Place-names in the British Isles involving all forms of the root Pakat have been classified under counties and their densities calculated. Goidelic forms where the initial *p* is dropped have been calculated as percentages of the total. Some of the conclusions arrived at are—that the density of the Picts was greatest in the south and midlands of England and in the east of Scotland, and least on the east coast of England, and in Wales. In Ireland the density was only about one-third that in England. The Goidels, who followed the Picts, spread along the valleys of the Thames and Severn to the Mersey, where a part probably crossed to Meath and spread in two streams to the west coast of Ireland; the other part moved northward through Lancashire, Yorkshire, Northumberland, and advanced into Scotland almost to the Forth. A second incursion entered Scotland by Argyll and spread along the west counties to the extreme north. The pre-Pictish inhabitants were probably Iberians, and prevailed mostly in Ireland, South Wales, Cumberland, and South Scotland. The oldest name of Britain, Albion, is derived from *Al*, the name of an Eastern god worshipped by the Picts, and *Bath*, a decayed form of the name Pict.

8. *On the Ceremonies observed by the Kandyans in Paddy Cultivation.*
By B. P. KEHLPANNALA.

WEDNESDAY, AUGUST 15.

The following Papers and Report were read:—

1. *On the Brain of a Young Fuegian.*
By Professor L. MANOUVRIER.

Professor Manouvrier described the brain of a Fuegian child, and compared several of its characters with those of the ordinary European brain. He pointed out that it is interesting anatomically, physiologically, and psychologically to find that the external morphology of the Fuegian brain is nearly equal in its development to that of the European, though some traces of inferiority exist in the former—as, for example, in the third frontal convolution, or the convolution of Broca. The author insisted on the physiological signification of the morphological development of the brain. He believes that the approximate equality of the Fuegian brain to the average European brain does not raise doubts as to the physiological value of cerebral morphology, but rather on the accuracy of the opinion usually held as to the intellectual inferiority of savage people. This inferiority, as that of the ancient Gauls in comparison to the Romans, may result much more from obvious defects in the external conditions which produce civilisation than from true physiological inferiority conjoined with anatomical inferiority. What makes the physiological value of the morphological development of the brain an unknown quantity is that other anatomical, physiological, or external conditions form with it very variable combinations in which the influence of each factor may be masked or counterbalanced by that of others.

2. *On the Valuation of Proportional Dimensions in the Description of the Brain. By* Professor L. MANOUVRIER.

3. *On the Classificatory System of Relationship. By* Rev. LORIMER FISON.

In this paper the author showed the arrangement of the classificatory system of relationship, and the key to it, by an examination of the descendants of two brothers and their two sisters to the third generation.

The Fijian terms of relationship were taken as an example of the system. These divide the sexes in any one generation into groups of non-marriageable persons and other groups of marriageable persons.

The same relatives and their descendants were traced in an Australian tribe, and it was shown that precisely the same groups appear as the result of the division of a community into two exogamous intermarrying divisions, such as are found in Australia.

The inference deduced by the author was that wherever the classificatory terms appear those divisions of the community exist, or have existed in the past.

4. *On some of the Natives of British New Guinea.*
By H. BELLYSE BAILDON, *M.A., F.R.S.E.*

The materials for this paper were obtained during a visit to British New Guinea in 1891, the incidents of which had been detailed by the author's sister in the Geographical Section. The author acknowledged his indebtedness to Mr. and Mrs. Chalmers for corrections and additional information.

The observations extended over the group of villages at Port Moresby, those in the Elema district about Motu-motu; the dangerous inhabitants of Movi-avi; and, again, further east, the people of Kerepuna and Hula.

The natives of Port Moresby consist of two very distinct tribes—the Motuans and the Koitapuans—located in three villages, the principal of which, Hanuabada (the Big Village), is built on the foreshore of the bay. Of the other two, one is on the mainland and the other on the beautiful island of Elevala. The juxtaposition of these two tribes is an instance of that curious intertribal commensalism or economic co-operation often found in New Guinea.

The *Motuans* (who must not be confused with the inhabitants of *Motu-motu*, a very different people) live chiefly by fishing and the manufacture of pottery, while the Koitapuans live mainly by hunting. Much traffic goes on between these two tribes, who supplement each other's requirements, so that commerce here, as in civilised communities, makes chiefly for peace. The Motu pottery is also made for purposes of trading with the Motu-motuans and other western tribes, with whom the Motuans exchange it for sago.

The people of the Elema country and the fertile land of sago about Motu-motu differ in many respects from the Motuans. They seem to be a wilder, more high-spirited and unruly tribe than the more industrial Motuans, who have been called the 'British' of New Guinea, while the others have been likened to the Irish. Nor is the comparison in the latter case without fitness also; for not only in their excitability and impatience of control, but also in their light-hearted gaiety and wit, the resemblances are not far to seek.

The social arrangements here are different from those at Port Moresby, where the people live *en famille* in their cottages; for in Motu-motu the men congregate in large club-houses or *dubus*, while the women and children live in smaller houses. Even married men live in these clubs, and, although they may visit their families, they must always return to the *dubu* before daybreak, otherwise they commit a serious breach of Papuan etiquette. These *dubus* are curious structures built on platforms 14 to 16 feet from the ground, and shaped like the open mouth of a shark. Under the great projecting upper jaw or gable the men lounge and smoke in the daytime, and have their food brought to them here by the women, who are strictly forbidden to enter the interior, which is *helaga*, sacred, or *tapu* to the men. In each village there are several *dubus*, occupied by different clans or families. At a certain age the boys of the clan are taken into the *dubu* to undergo initiation, have their heads shaved, and remain in seclusion till their hair is fully grown.

The remainder of the paper dealt in a similar way with inhabitants of Movi-avi and Kerepuna.

5. *On the Tobas of Gran Chaco, South America.* *By* J. GRAHAM KERR.

The author gave a short account of the manners and customs of the Natokoi or Tobas of the Gran Chaco. This region is inhabited by very numerous nations of American Indians, differing markedly in language, customs, and in minor physical characters. The Tobas are exclusively nomadic in their habits, living entirely on the products of the chase. They usually go about in small hunting parties, larger tribal encampments being only formed occasionally, *e.g.*, at particular seasons. In regard to their mental characters, it was pointed out that they appeared to believe only in the existence of numerous minor evil spirits, who were the causes of disease, accidents, defeats in battle, and other misfortunes; and that their arithmetical powers were very limited, the limit of counting being usually about five.

6. *On the Maya Indians of Chichén Itzá, Yucatan.*
By ALFRED P. MAUDSLAY.

In this paper the author gave an account of some excavations of a burial-mound in the Vera Paz of Guatemala, and the discovery of little jars containing the bones of the little fingers probably deposited by mourners.

The earliest notices of the great Maya ruins at Chichén Itzá, in Yucatan, were discussed, and extracts given from a document lately found by Dr. Marimon in Seville, describing the ceremonies still performed by the Mayas at the great Cenote at Chichén at the time of the Spanish conquest, although the town was already abandoned and the buildings in ruins.

A description was given of the great tennis-court, and a model of it exhibited. The paper concluded by calling attention to some photographs of a hitherto unknown Maya monument at Ixkum, in which the supporters of the Maya figures are captives bound with cords, who are altogether unlike the Mayas in appearance, and probably belong to another race.

7. *On the Loochooan Language.* *By* Professor BASIL HALL CHAMBERLAIN.

Hitherto only two languages have been generally recognised as spoken in the Japanese Empire—viz. Japanese proper, and Aino or Ainu, the language of the hairy aborigines of the north. Professor Chamberlain's paper contains a preliminary sketch of his analysis of a third language—Loochooan—known hitherto, or one might better say suspected, only from a short and exceedingly imperfect vocabulary by the late Lieutenant Clifford, R.N., appended to Captain Basil Hall's

'Voyage of Discovery to the Great Loochoo Island,' published in the year 1818. Mr. Chamberlain has now ascertained that Loochooan stands to Japanese in about the same relation that Spanish does to French. The importance of this discovery will be best appreciated when it is remembered that the Japanese language had hitherto stood in a position of complete isolation, without kindred of any sort. With this new key it will be possible to solve many difficult questions of Japanese philology, and in the paper the author discusses the formation of the negative conjugation of Japanese verbs from this new point of view. Mr. Chamberlain also establishes the fact that Japanese, as we now have it, is the language of the invaders of the Archipelago, not that of the previous inhabitants, by whom the invaders might be supposed to have been absorbed.

8. *Report of the Committee on the North-western Tribes of Canada.* See Reports, p. 453.

9. *On the Significance of Objects with Holes.*

By Miss A. W. BUCKLAND.

This paper treats of what appears to be a world-wide superstition, belonging to all races and to all time, in which holes are credited with healing and protective powers.

The superstition exists among us at present in the shape of lucky money and lucky stones, but can be traced back to Neolithic times, in the great holed stones and dolmens which are found in Great Britain and Ireland as well as in many countries of Europe, in North Africa, India, Syria, Circassia, and also in America. The chief of British holed stones, the Men-an-tol, is still known locally as the Crick-stone, and through it people creep for the cure of rheumatism.

In Siberia wooden figures bored with holes are carried about as a cure for various diseases, according to the part in which the hole is bored; and figures of great age have been found in Peru and among the Eskimo, which seem from the holes in them to have been intended for the same purpose. Engraved shells also similarly bored have been found in ancient Chaldea and in the American mounds.

The same superstition appears to be traceable in the trephined skulls of Neolithic times found in many countries, and from which amulets have been cut, probably for the cure of epilepsy, the disease for which the operation was undoubtedly undertaken, since it was thus employed up to quite recent times; and the bones of the human skull were always recommended, either grated as a potion, or worn as an amulet, for the cure of epileptic disease.

Miss Buckland believes the healing property thus attached to holes to be of necromantic origin. She regards the hole as the symbol of the underworld, the abode of the Creator in some cosmogonies, and always of the spirits of dead ancestors. Hence they are summoned by the medicine-men to assist them in their healing ceremonies and magic incantations; and thus the hole, through which they are drawn by sorcery, became to the savage the source of healing, and in this form, modified by time, it has descended to us.

The underworld also was the reputed source of wealth; hence the symbolical hole in money caused it to be regarded as lucky money, and this probably explains the use of ring money among the ancients. These symbolical holes are also found in ceremonial weapons in West Africa and in the South Sea Islands, as they were also probably in Ancient Egypt and other countries; the idea suggested being that the bearer of the weapon assumed the power of sending offenders to Hades. Holes exist also in magic wands and in staves, especially in the South Sea Islands, where the holes certainly represent deceased ancestors.

The magic wands and the South Sea staves or idols resemble so strongly the holed implements of reindeer horn found in caves of Palæolithic times, that Miss Buckland believes these staves also to have been used by the medicine-men of that remote period as symbols of the world of spirits over which they assumed control, and that thus we can trace the superstitions connected with holes to the earliest of the human race.

Section I.—PHYSIOLOGY.

PRESIDENT OF THE SECTION—Professor E. A. SCHÄFER, F.R.S.

THURSDAY, AUGUST 9.

[The President's Address was delivered on Friday, August 10.—See p. 795.]

THE following Papers were read:—

1. *The Response of Animals to Changes of Temperature.*
By M. S. PEMBREY, *M.A., M.B.*

The simplest method of investigating the response of animals to changes of temperature is to determine the amounts of carbonic acid which they discharge. The carbonic acid is a measure, it may be not an exact one, of the heat produced. From this point of view a series of experiments have been made upon the power which warm-blooded animals possess of varying their production and loss of heat in such a way that their mean temperature is constant.

A mouse is a very suitable animal for such experiments, because on account of its large cutaneous surface compared with its small bulk the reaction to a change of temperature is very rapid. Within two minutes of a fall in external temperature from 30° to 18° the mouse increases its output of carbonic acid by 74 per cent.; within one minute of a change from 33°·25 to 17°·5 the increase is 60 per cent. The response to a rise in temperature is not so rapid: within two minutes of a rise from 18° to 34°·5 the decrease in carbonic acid is 18 per cent.; within one minute of a change from 17° to 32° the decrease is 5 per cent. With cold surroundings the mouse is very active, whereas with a warm temperature it becomes quiet and goes to sleep. The relationship between muscular activity and the production of heat is well shown.[1]

Experiments were next made upon the developing chick. It is a warm-blooded animal, but during its development it was probable that it passed through a stage in which it would have responded to changes of temperature in a similar way to that seen in cold-blooded animals; that in cold surroundings it would have produced less carbonic acid, but that with a rise in temperature it would have increased its output of carbonic acid. The experiments show that during the greater part of the period of incubation the developing chick responds to changes of temperature in a similar manner to that of a cold-blooded animal; that towards the end of incubation, about the 20th or 21st day, there is an apparently neutral stage in which no marked response is seen; that this neutral condition is succeeded, when the chick is hatched, by a warm-blooded stage. The intermediate stage may be the resultant of two opposite tendencies—on the one hand the cold-blooded condition, on the other the imperfectly developed power of regulating the production of heat. When the developing chick is exposed to shock by the prolonged action of cold, this neutral condition may be replaced by a return to the cold-blooded stage.

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[1] 'On the Reaction-time of Mammals to Changes in the Temperature of their Surroundings,' *Journal of Physiology*, xv. 1893, p. 401.

The reaction of the recently-hatched chick is rapid; a fall of 20° in temperature will within fifteen minutes raise the carbonic acid to double its previous amount.

It would appear that this power of regulation depends upon the integrity and full development of the nervous control of muscular action. The chick directly it is hatched possesses great control over its muscles; it is able to run about, feed itself, and perform other complicated movements. At the same time it is able to regulate its production of heat.

It was probable that animals born blind and in a very helpless condition would not possess this power of regulation; that in their case a fall in external temperature would be accompanied by a decrease in carbonic acid, and that with a rise of temperature the output of carbonic acid would be increased. This has been proved to be true in the case of the pigeon. A young pigeon was examined, when it was one day old, and it was found that a fall of 14° in external temperature caused the carbonic acid to diminish to one-third its former value within thirty minutes of the change in temperature. When two days old a similar change of temperature produced almost as great a fall in the output of carbonic acid; raising the temperature to its former level did not cause the carbonic acid to increase with the same rapidity with which it had fallen.

Thus a young pigeon resembles to a certain extent a cold-blooded animal. There is, however, one great difference. The young pigeon responds very rapidly, the frog responds extremely slowly.

To study still further the influence of the nervo-muscular system upon the regulation of temperature by the production of heat, experiments have been made upon mice after section of the spinal cord and during anæsthesia. Both these procedures tend to make the mouse respond in a somewhat similar way to that observed in the cold-blooded animal.

The writer has to thank Messrs. Gordon and Warren for much assistance in some of the experiments.

2. *On some Experiments to determine the Time-relations of the Voluntary Tetanus in Man.*[1] *By* DAVID FRASER HARRIS, *B.Sc. Lond., M.B.*

1. In a large number of experiments the following apparatus was used:—

A metallic case, made air-tight at each end, was fitted over the forearm from below the elbow to near the wrist. This instrument, practically an air-plethysmograph (for it could register the pulse-beats), had a circular aperture cut in the upper surface, and over this space was fastened a membrane of gold-beater's skin, to which was fastened a disc of platinum. There was no tension exerted on the membrane, which the slightest increase of pressure caused to move, but which, on the cessation of the agitation, came immediately to rest.

Touching the platinum disc was a fine metallic point—the end of a screw supported by an upright soldered to the metallic case. A wire was led to a battery, thence the current traversed an electro-magnetic writer (or 'signal'), and the circuit was completed to the screw-point. The vibrations of the muscles of the forearm thrown into voluntary tetanus (*viâ* the air under the membrane) agitated the membrane, and so made and broke the current, these interruptions in turn synchronously affecting the writing style of the electro-magnet, which traced on a revolving drum a myogram of 'incomplete' tetanus. The rhythm of this as computed from nine different parts of a tracing varied thus: 10, 12, 23·3, 10, 10, 20, 20, 20, 26·6 vibrations per second, or on an average 16·8. The average of a very large number of computations was 13·3.

2. The method employed by Schäfer[2] gave exactly similar results—viz. an average of 10, 8 to 13 being the minimum and maximum rates respectively.

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[1] The paper is published in the *Journal of Physiology*, October 1894.

[2] *Journal of Physiology*, vol. vii.

3. This method was modified as follows:—

A steel spring, strongly clamped at one end, was arranged so that its free end could be bent back to touch a hinged upright connected with a tambour; the recording tambour was in connection as in method 2. By pulling on the spring by the index-finger (the corresponding thumb being at the fixed point of resistance) the vibratory movements of tetanic muscles are communicated through the spring to the air, and so to the recording tambour. The graphic representation of this is very similar to that in 2.

The figures in a typical set of tracings were 9, 6·6, 10, 11·3, 14, 17, 13, 11·7, 18. The average of a large number of experiments was 12·5 vibrations per second.

4. In this, the apparatus was as in 3, except that the myogram was taken on a rotating cylinder, which also oscillated transversely seventeen times per second. The tracing was in places identical with that obtained when one combines two wave-systems whose periods are as 1 : 2; in other places there was a perfectly simple wave-form.

It is contrary to all we know to suppose that the tetanus had twice the rate of the cylinder—viz. 34; the contrary must be true.

If, then, the tetanus had at times a rhythm of 8·5 per second, and at times rose to 17, the mean is 12·75.

5. By a method employing a carbon resistance pile (upon which the muscle was pressed) in the primary circuit of the inductorium, a capillary electrometer in the secondary, and viewing the electrometer through a stroboscopic card, a rate of 12 per second was estimated.

6. By experiments with the microphone, on which the muscle was laid, the rest of the connections being as in 5, the rate was fixed at 12–15.

7. By the microphone laid over the contracting biceps, and a frog's gastrocnemius stimulated by secondary shocks (the microphone being in the primary circuit of inductorium), a rate of 8–15 was estimated, or an average of 11·5 vibrations per second.

The average of these and very many other experiments is 12·5 per second.

3. *On Mirror Writing. By* Professor F. J. Allen.

4. *On a Model of the Cochlea. By* John G. M'Kendrick, *M.D., F.R.S., Professor of Physiology in the University of Glasgow.*

Professor M'Kendrick exhibited a working moded intended to illustrate the mechanism of the cochlea, devised by himself, with the aid of valuable suggestions by Professor Crum Brown. It consisted of a water-tight glass tank divided into two compartments by a horizontal glass diaphragm. At the end of each compartment a round hole was cut and covered with an india-rubber membrane. The upper hole represented the *fenestra ovalis*, and the lower the *fenestra rotunda*. The horizontal glass plate had two holes cut, each of which was supplied with an india-rubber membrane, and on each membrane there was a steel watch-spring tuned to vibrate at a certain rate. The vibrations of the two springs were as 2 : 1. An arrangement was used for imitating the movements of the stapes, consisting of a rod caused to oscillate horizontally by an eccentric wheel. In this way pendular vibrations were transmitted by the *fenestra ovalis*, and it was shown that when the number of pushes made by the base of the stapes corresponded to the period of spring A, spring A began to vibrate; if the number of pushes was increased A ceased to move; and when the pushes reached the period of B, the latter began to move. Finally, by an appropriate harmonic motion, the wave form of two vibrations of 2 : 1 was transmitted to the *fenestra ovalis*, and both springs vibrated when the period of A was reached, thus showing that the apparatus analysed the compound wave-form. The model generally supported the Helmholtz-Hensen theory of the cochlea. Professor M'Kendrick stated that the Royal Society had enabled him to continue the investigation, and that a more refined apparatus was in course of construction.

5. *On some Physiological Applications of the Phonograph. By* JOHN G. M'KENDRICK, *M.D., F.R.S., Professor of Physiology in the University of Glasgow.*

Professor M'Kendrick exhibited one of the newest forms of the phonographs of the Edison-Bell Corporation, and by the aid of a large resonator adapted to it by himself he was able to cause the instrument to speak so loudly as to be distinctly heard throughout the large room in which the Section met. He explained the mechanism of the instrument, and showed how it might be adapted for recording the voices of two persons at one time, and for transmission of speech to a distance, by using along with it a microphone in a telephonic circuit. He also described attempts he had made to register the voice curves by means of a small and light lever running along the grooves and recording on a small smoked cylinder travelling at a slow rate, and he exhibited curves obtained in this way. His method was quite different from that employed by Professor Hermann, of Königsberg. These curves showed long undulations, at periods of about one second, with the speech curves superposed on these. He also explained methods by which the phonograph might be used for recording respiratory and cardiac sounds, and he stated that, whilst he had been as yet unable to record cardiac sounds, he had obtained several respiratory curves, and also the sound of the ticking of a watch. He announced his intention of continuing the investigation with more delicate apparatus.

6. *On Trophic Changes in the Nervous System.*
By JUSTUS GAULE, *Professor of Physiology, University of Zürich.*

The author has been able by experiments upon the inferior cervical ganglion of the sympathetic to bring about changes in different organs, especially in the biceps and psoas muscles. As the result of further research, he is able to follow out the trophic effect from the spot where the operation is performed up to the organ which subsequently undergoes change. The pathway of this trophic effect passes through the spinal cord; the author in previous communications had already pointed this out as the probable pathway, and now this supposition has been confirmed by microscopical examination. It has been found that the path is marked out by changes of a trophic nature in the nervous system, passing from the point of section to the organ which undergoes change. It was necessary in order to remove any doubt to perform the experiment in such a way that the injury caused by the operation could have little or no part in bringing about the changes in the nervous system.

At last it was found that the trophic changes took place throughout the whole length down to the biceps or psoas muscles when a special nerve scarcely visible to the naked eye was cut away with scissors from its ganglion. This nerve joins the ganglion near the spot where one of the accelerator nerves arises. When the operation is performed in this way the injury is so slight that if the section does not involve the right part of the nerve there are practically no after-effects to be observed in the animal. We must therefore attribute to a special trophic influence those changes which can be observed after the section of the nerve has been properly performed. The changes can be classified according to the different parts of the trophic path in which they lie:—

Those of (1) the sympathetic ganglion; (2) the rami communicantes; (3) the
ave ganglia and posterior roots; (4) the spinal cord; (5) the anterior roots and
(6) the smaller divisions of the nerves in muscle; (7) the nerve-
cle; (8) and lastly those of the muscle itself.

[1] T

[2] *Jou.*

The changes in each of these parts are of so special a nature that it is impossible to give a short general description of them. In general the changes are of such a kind as if the operation caused some substance to be formed or to soak into the ganglion, and then spread along its nervous connections, bringing about changes in the chemical conditions of the cells of the tissues until the cells are more or less completely destroyed. The alteration spreads along the natural pathways only as long as they are intact; every experiment therefore which destroys the connection produces no trophic effect. It appears that a spread of this injurious substance is possible both in the special ganglia and in the grey substance of the spinal cord, for the number of altered cells is far greater in the case of the spinal ganglion than in that of the sympathetic ganglion. In the grey substance of the spinal cord the change is seen to spread, not only from the posterior to the anterior horns, but also in the direction from above downwards. In those places where the change has reached the anterior horns it spreads through the anterior nerve-roots, and thus arrives at the muscles. At least one finds in the fibres of the nerves which supply the biceps muscle characteristic changes throughout the whole course of the nerves down the brachial plexus to the muscle.

7. *On the Development of Kidney.* *By* JOHN BERRY HAYCRAFT, *M.D., Professor of Physiology, University College, Cardiff.*

The epithelium of the kidney tubules is originally derived from that of the ureter and Wolffian duct, as taught by Kölliker. In the rabbit the ureter branches in the kidney blastema into six or eight tubules, ending in peripheral dilatations, the primitive renal vesicles. These vesicles divide again and again as the kidney grows, keeping to the extreme cortex, and their stalks forming the collecting tubules. All the primary branches of the ureter and many of the above-named collecting tubules become evaginated to form the pelvis. From the primary renal vesicles the rest of the tubules grow out as solid and then hollow processes and the Bowman's capsule is moulded on a bend of its own tubule, and is not invaginated by a glomerulus. After birth the primary renal vesicles shrink down to the size of an ordinary tubule, but at birth they may be seen as dilatations of the collecting tube when it reaches the extreme cortex and turns round into the region of the convoluted tubules.

FRIDAY, AUGUST 10.

The President, Professor E. A. SCHÄFER, F.R.S., delivered the following address:—

BEFORE beginning the subject-matter of my address I had conceived it to be necessary, appearing before you as we do as a new Section, to offer some sort of apology for our presence. But, on looking up the history of the Association, I find that my task is somewhat different. If I have any apology to offer at all it is that the Section of Physiology has ceased to appear for many years.

The British Association was founded at York in 1831; and at the subsequent meeting, which was held in this very city of Oxford, amongst other Sections which were established, was one for Anatomy and Physiology. Now, when we consult the records of this Section we are struck with the fact that Medicine early shows a marked preponderance. Thus, in 1833 a physician, Dr. Haviland, is selected as President for the Section; and the secretaries are Dr. H. J. H. Bond, who was Regius Professor of Physic in the University of Cambridge from 1851 to 1872; and Mr. (afterwards Sir) G. E. Paget, who succeeded Dr. Bond in the Regius Professorship. This preponderance soon came to be recognised in the designation of the Section, for in 1835 we find it entitled Section E, Anatomy and Medicine.

As time went on the interests of medical men became gradually more absorbed in the rapidly growing British Medical Association; and in 1841 the medical title was dropped, and the Section came to be called simply Physiology, which title it retained until 1847. Under that designation the Section has now been revived.

The fact that Physiology as a separate Section in this Association was allowed to lapse for so long a period is not remarkable when we remember that during the first half of this period Physiology as a science was practically non-existent in this country. The teachers of Physiology were, almost without exception, practising physicians and surgeons, and even when a professor was expected to devote his time to the teaching of Physiology he was not expected to devote part of that time to the prosecution of physiological research. During all these years, from 1833 to 1847, we do not find amongst the officers of the Section any actual working physiologists. Most of the officers were distinguished medical men, with an anatomist here and there amongst them. Far be it from me to say that there was no actual work being done in Physiology at this time; for Charles Bell and Marshall Hall were engaged in elucidating the functions of the nervous system; whilst Bowman, Wharton Jones, and others were producing good and permanent work in various other departments of Physiology. Their labours, however, were isolated, and formed but oases in the Sahara of neglect into which the pursuit of Physiology had fallen in this country; and this during a period when it was being pursued with signal success and activity both in Germany and France.

After 1847 a revival of Physiology began to manifest itself even here; and this was followed by the establishment, from time to time, of a sub-section to Section D, which was devoted to Physiology, and had a special President. Whether, however, owing to their subordinate character, or from some other reason, these sub-sections had not usually any great measure of success, and for the last twelve years they have been wholly dropped. During that period Physiology has only twice been represented in the Chair of Section D, and has usually had no secretarial representation. This decadence of Physiology in the British Association during the last eleven or twelve years is the more remarkable because it is obviously not due to any want of outside activity in regard to the subject; for during this period we find an extraordinary revival of interest in physiological research, a revival which in its most active stage dates from about twenty-five years ago, but still some twenty or thirty years later than the corresponding revival in France and Germany. I have taken the trouble to prepare a list of prominent physiological workers who flourished during the thirty years prior to 1870. My list comprises, in all, thirty. Of these, four are English, five French, and twenty-one German or Dutch. Of the four English working physiologists not one is a teacher of Physiology. Of the five French and twenty-one German all are recognised teachers. It was not, in fact, until it came to be understood that teaching and work in Physiology, as in all branches of science, ought in the main, to be successful, to go hand in hand, that the science had any possibility of revival.

Let us glance for a moment at the history of the revival of Physiology in this country as compared with its revival in Germany. In each country the revival may be said to have been largely due to the influence of one teacher. In Germany the teacher was Johannes Müller; in this country, William Sharpey. Both of these remarkable men were pupils of Rudolphi, who was Professor of Anatomy and Physiology in Berlin until 1833. It is stated regarding Rudolphi that 'he was an enemy to subjective speculation in biological science: he looked on the so-called philosophy as mistaken and futile in its application to the phenomena of the animal economy, and based his physiology chiefly, and perhaps rather exclusively, on the study of the animal structure.' The influence of Rudolphi is apparent in both Müller and Sharpey.

Müller was born in 1801, Sharpey in 1802; they were therefore of about the same age. But Müller's scientific and intellectual development was more rapid than that of his contemporary. Thus we find that already in 1826, when he was but twenty-five years old, Müller attained so great a reputation as to be made Professor Extraordinary in the University of Bonn; and before very long he was promoted to the grade of Ordinary Professor there. In 1833, whilst still a young man, he was called to the chair of Anatomy and Physiology at Berlin, which had just become vacant by the death of his master and friend, Rudolphi. Sharpey, on the other hand, occupied himself until 1820 with perfecting both his general and his special anatomical education. It was not until 1830 that he published his first essay in anatomical and physiological research entitled 'On a Peculiar Motion excited in Fluids by the Surfaces of Certain Animals'—observations which were preliminary to the discovery of the existence of cilia in vertebrates. And it was not until 1836 that he was called to the newly instituted professorship of Anatomy and Physiology in University College, London, which he filled for so many years with such signal success. Both of these distinguished men owed, there is no doubt, their success as teachers of Physiology to their early anatomical training. The general anatomical bent of Johannes Müller is evidenced by the fact of his scientific work being turned so much in the direction of Comparative Anatomy and Physiology. And Sharpey, although great, and deservedly great, as a teacher of Physiology, remained to his dying day, above all, an anatomist. Physiologists of this school are rare at the present day; but it is probable that in some respects the progress of Physiology may suffer thereby. Helmholtz began his public career as professor of Anatomy; but it would be unfair to attach too much weight to this particular incident in the case of so many-sided a man as the great Berlin Professor of Physics. Nevertheless, the necessity of a close and careful training in Anatomy for those who are afterwards to work at or to teach Physiology is so important that I do not hesitate to say that the younger physiologists who neglect the study of Anatomy will find that before very long they must abandon the pursuit of many byways of Physiology which might otherwise be followed up with manifest advantage.

The influence of Johannes Müller upon the revival of the pursuit of Scientific Physiology in Germany, and indeed generally, cannot be overestimated. We have only to look at the names and eminence of his pupils in order to recognise the immense influence which his teaching has exerted upon the progress of Physiology ever since his time. Some of these pupils are still amongst us, others have joined the majority. But the pupils of these men, again, are now great names in many departments of our science, and through them we cannot fail to recognise the influence which was exerted by this truly great man.

We may say the same in almost identical words of William Sharpey. The practical pursuit of Physiology in this country has mainly radiated from the centre where Sharpey taught. Michael Foster was his pupil. The physiological investigations of Burdon-Sanderson were assisted and encouraged by him. From Sharpey, therefore, we may trace the rise of the great school of Physiology at Cambridge, and we have only to look at the magnificent laboratory which has been erected here to observe a monument of the influence of the same teacher. And there have emanated either directly from the physiological school established by Sharpey at University College, or indirectly from those at Cambridge and Oxford, many of the most active teachers and workers in Physiology in the kingdom.

In these respects there is much in common between the revival of Physiology in Germany and in this country. In other respects, however, the two cases have been entirely under different conditions. There its revival, in common with that of science generally, has been assisted and stimulated by the active and beneficent co-operation of every German State. Here, also in common with science generally, it has had to make its way against every conceivable obstacle; and almost without assistance, either moral or material, from the Government or from public bodies. But not only has it not met with assistance, there have been actual obstacles placed in the way of teaching and work in Physiology. Some have been unintentional, others intentional. As an instance of the unintentional may be mentioned the practice which has obtained in medical schools and on examining boards—a practice which, I am happy to say, is gradually being discarded—of appointing as teachers and examiners in Physiology men who may have a good general knowledge of the science, yet with whom it is not the business of their lives, and who cannot, therefore, be expected to be as familiar with its details, and as absorbed in its interests, as those who devote their entire time and attention to its pursuit.

The more virulent opposition, in some measure, to science generally, but in the greatest measure to Physiology, appeared almost simultaneously with the active revival of the subject. This opposition, which has come to be known as the Anti-vivisection Movement, but which might equally well be called the Anti-scientific Agitation, has hitherto met with no measure of success, except that it has to a certain extent hampered the full development of the science by diverting to its defence some of the energy which might be devoted to its pursuit. Indeed, the actual results of this unreasoning agitation furnish an illustration of the old-established principle that persecution of a good cause will in the long run tend towards its development and propagation. And in this case the chief results have been the following:—

1. The most immediate effect of the anti-vivisectionist attack was the establishment of the Physiological Society, which in the first instance was only a small gathering of working physiologists, who met to discuss measures of defence in a drawing-room in Queen Anne Street. This society, which had such a small beginning, is now large and important. Its doors are besieged by applicants for admission, although it is a necessity for such admission that the applicant be either a teacher of Physiology or a worker at Physiology, or both. Its numerical strength has grown from ten or fifteen to more than 150; and its numbers are every year increasing. And, besides the work which it has done in this country in promoting the interests of Physiology, and co-operation between English physiologists, it has succeeded in establishing a succession of Triennial International Congresses of Physiology, which are amongst the most successful of such gatherings, and which have been the means of bringing us into communication with the most prominent physiological workers and teachers on the Continent.

2. A second result of the agitation was the passing of the so-called Cruelty to Animals Act. This Act, which was intended to restrict the performance of experiments upon animals, was in no sense called for, since it had been found by a Royal Commission that there was no evidence to show that there had been unnecessary experimentation upon animals, or any desire on the part of physiologists to neglect the use of anæsthetics. On the other hand, it is of inestimable advantage in that it gives the public a definite guarantee that the excesses of which physiologists used to be freely accused are not possible. Such excesses never did actually occur; although, to believe all the publications which have been issued by Anti-vivisection Societies, one would come to the conclusion that a physiologist is a being who spends his whole time in torturing sensitive creatures, careless of the suffering which he may cause, or even of the scientific results which he may obtain. The fanatical supporters of the agitation would have you to believe that we are all neither more nor less than 'fiends;' they cry with Ferdinand that 'hell is empty and all the devils are here.'

I am told there was even a feeling of this sort in this University at the time when it was proposed to establish the Waynflete Professorship of Physiology, and that an agitation was set on foot having for its object, first, the prevention of the establishment of such professorship; and secondly, that being impossible, the prevention of the professor's practising Physiology. The common-sense of the University stifled this agitation, and the more intimate acquaintance with physiologists which has resulted from the establishment of the school has been sufficient, I believe, to smother the little fire which was still left smouldering.

3. A third result of the Anti-vivisection Agitation was the establishment of the Association for the Advancement of Medicine by Research. This immediately followed a unanimous resolution of the International Medical Congress of 1881, affirming the necessity of experiments upon animals. To the ignorant accusation that physiological experiments had been and were of no use or influence in the advancement of medicine, the leaders of the profession unanimously affirmed that it is upon Physiology that Medicine and Surgery are based, and that there can be no real progress in those sciences without a corresponding progress in Experimental Physiology and Pathology. The Association for the Advancement of Medicine by Research has been of the greatest possible value and assistance to Physiology in this country. It has shown physiologists that they have the great

medical profession at their back, and it has acted as an impartial and independent medium of communication between physiologists and the successive Secretaries of State, whose business it has been to administer the Act.

4. A fourth result of the attacks of the anti-vivisectionists has been, I may perhaps be permitted to believe, the re-establishment of this Section of Physiology of the British Association. Those who were present at the meeting of the Association in Nottingham may have remarked that the gutters of that town were strewn with papers which had been forced upon the members of the Association by the anti-vivisectors of the place. This literature, which in a double sense may be termed 'gutter literature,' teemed with flagrant misstatements, and with vicious calumnies, directed against physiologists, and especially called forth, I presume, by the fact that for the first time in the history of the British Association a physiologist was called upon to occupy the presidential chair. We may look upon the establishment of this Section as the reply of the Association to the false witness which was borne against us at Nottingham.

But although a special section for Physiology has been re-established, it may not be advantageous that there should be one at every meeting of the Association. Physiology is above all things a practical science. It requires laboratories and means of demonstration. Physiologists are rarely satisfied with the opportunity of hearing and reading papers, but require that, as much as possible, the actual methods of research employed should be capable of demonstration. By this I am not to be supposed to advocate the demonstration of experiments upon animals, for there are very many subjects in Physiology which can be both worked at and illustrated in a manner involving in no sense whatever the word vivisection. But in order that the methods should be shown, it is important to have the appliances of a laboratory at hand, and the Association frequently meets in towns which are not university towns, and have no laboratories, in which, therefore, it would be difficult or impossible to arrange for demonstrations of the sort that I am alluding to. On this account we may well imitate the practice of the British Medical Association, which establishes a Section of Physiology only when its meetings are held in such a centre as is likely by the appliances which are to be found in that centre to render the Section useful and efficient. Hence, in recommending the establishment of a Physiological Section, it is expressly reserved that the Section shall be held only at such future meetings as may seem to the Council to be desirable.

I will now invite you to consider with me one or two of the more obscure subjects in the range of Physiology, subjects which are, however, creating a great, almost an absorbing, interest at the present moment. The first of these subjects relates to the structure and function of every cell in the body. All are aware that the body of every animal and of every plant is made up of minute corpuscles which are formed of protoplasm, and which contain in every case at least one nucleus. The protoplasm and the nucleus form the living substance of the cell. Other substances may be present, but they are, in a sense, outside the nucleus and protoplasm, not incorporated with their substance. Apart from a few details relating to the structure of the nucleus, this was, until quite lately, practically all that we knew regarding the parts composing either the animal or the vegetable cell. There appears, however, to be yet another something which, although in point of size it is of very insignificant dimensions, yet in point of function may perhaps be looked upon as transcending in importance, in some respects, both the protoplasm and the nucleus. Not many years ago it was noticed by various observers that in certain specialised animal cells the protoplasm showed a tendency to radiate from or converge towards a particular point, and on further investigation it was found that at this point there was a minute particle. This observation, which began, as we have seen, upon specialised cells, was, after a little while, found to hold good for other and yet other cells, until, at the present time, we believe that in every cell of the animal or plant body such a particle exists. Now, it may well be asked, why after all should so great importance be attached to this observation? To this it may be replied that, in the first place, it is of importance, because it shows conclusively that the whole cell is not of a uniform nature, since there is this one point within the cell that exerts a special attraction upon the rest of the cell-substance; and, indeed, on this account the particle has come to be termed the 'attraction particle.' And in the second place, because of the apparent universality of the occurrence of such a particle. And, thirdly, because of the fact that one of the most important phenomena exhibited by the cell hinges upon the behaviour of this particle; for it is found that before a cell or its nucleus divides this minute attraction particle begins by itself dividing, and is, in fact, more commonly met with double than single. Nor is it until the two particles thus produced have evolved, either from themselves or from the substance of the protoplasm or nucleus, a system of communicating fibres, the so-called *achromatic spindle*, that those changes in the nucleus and protoplasm take place which produce the division and multiplication of the cell. This *attraction particle*, which is also called the *central particle* or *centrosome*, has absorbed so great an interest that, short as is its history, many papers have already been devoted mainly to it, the latest of these being an elaborate treatise of some 300 pages by Martin Heidenhain. I shall not here attempt to follow out the details of all these researches, but will be satisfied with putting before you the conclusion which Heidenhain has come to regarding this particle, viz., 'that it is morphologically, physiologically, and chemically a structure *sui generis*; not merely a separate portion of nucleus or of protoplasm, but an organ of the cell with definite functions, and having a definite existence of its own.' Nevertheless, it is almost as minute an object as it is possible to conceive. In a cell which is magnified a thousand diameters the central particle appears merely the size of a pin-point. Yet this almost infinitely small object exerts an extraordinary influence over the whole cell, however large (and the cell may be many thousand times its size), for it initiates and directs those processes which result in the multiplication of the cell, and indirectly, therefore, it is concerned in directing the general growth of the individual, and ultimately the propagation of the species.

A former President of the Association took as the subject of his presidential address what he was pleased to call the 'Next to Nothings.' In considering this central particle, of the actual structure of which, and of its chemical constitution, we know at present hardly anything, we may surely regard it as a striking instance of the supreme importance of the 'next to nothing' in Physiology.

The other subjects to which I desire to draw your especial attention relate to the physiology of certain organs the functions of which have always been extremely obscure, and which, although they differ greatly from one another in almost every point of structure, and presumably also in function, it has been usual to group together under the name of ductless glands. The name 'gland' is given to such organs of the body as take materials from the blood, and convey those materials in an altered or unaltered form, by a tube or duct, to a surface either internal or external. Such material is termed the secretion of the gland, and has for its object either the performing some function which is useful to the organism or the getting rid of material which would be detrimental if retained. In the case of the ductless glands there is no such possibility of pouring out material produced by the gland upon a surface, because these organs do not communicate with any surface by a duct; and whatever material they may furnish must therefore, if it is to reach the body generally, pass into the blood; that is to say, the blood on the one hand must furnish the materials for the secretion of the gland, and on the other hand it must take up those materials after they have been manufactured into something else, and carry them away to other parts of the body. Now, in the case of a certain number of the ductless glands there has not appeared to be any very great obscurity as to their function; for some of them seem very obviously to be devoted to the formation of corpuscles which are found within the blood itself. But with regard to others of these bodies it has not hitherto been possible to find any special material in the blood which they have furnished to it, and our knowledge of them is derived almost entirely from experiments. I will take the case of two of these to illustrate the vast influence which small and almost disregarded organs may exert upon the whole economy. But in the first place I may be permitted to point out what is indeed a self-evident statement, that there is no part of the body which does not exert some influence upon the rest. Every single portion of the body is continually taking materials from the blood, and furnishing to the blood other materials which are formed within it, whether we call that portion which performs such functions a gland or not; and it is quite certain that the removal of any portion of the body would be followed by some permanent alteration in the blood were it not that other similar parts may by increased activity compensate for the alterations which the blood would otherwise undergo from the loss of any one such part. Take the case of a limb. The changes which the blood undergoes in circulating through it affect the body generally through that fluid, for the composition of the blood becomes modified in traversing the limb. And not only is the body affected thus through the medium of the blood, but, by means of the nerves which pass to and from the limbs, the central nervous system is itself affected by the movements and alterations of various kinds which are proceeding in the muscles and other parts, and through the nervous system the whole organism must constantly be influenced from the limb. There is, however, no evidence that the removal of a limb or part of a limb permanently modifies either the condition of the blood or of the nervous system. Nor is such a result to be expected, for in this case there are other parts of the body possessing similar organs and performing similar functions, the increased activity of which may easily compensate for the loss which is sustained through removal of such a part.

But if we deal with an organ which is not multiple, but unique, and completely remove this from the body, it is easy to see that the case may be very different. This organ, like every other organ of the body, is continually taking from the blood some materials and giving up to it certain other materials. Now it is clear that its removal must make a permanent difference in the blood, and, since the whole organism is remarkably sensitive to even slight changes in the composition of the circulating fluid, very marked results may well follow the removal of such organ. And this is in fact found experimentally to be the case.

It has long been known that extensive disease of the thyroid gland, a small reddish organ, weighing about one or two ounces, found at the front of the throat, is followed by extensive alterations in the nutrition of the body generally. The patient becomes swollen from the overloading of the connective tissues with a mucinous exudation; the nervous and muscular systems are seriously affected; the power of generating heat is greatly modified; and the final result is, in the first instance, the production of a condition of semi-idiocy, ultimately followed, if the disease be extensive, by death. Precisely similar results have been found in animals, and in fact in man as well, to follow the complete removal of this body. Yet the weight of this organ is not more than one sixteen-hundredth part of the whole weight of the body; and even this figure does not represent the enormous influence which a relatively small organ can exert upon the general nutrition of the body; for it is found that even if a minute part of the thyroid gland be left whilst the greater part is removed, the symptoms above enumerated do not supervene. Indeed, certain contradictory results which have been got by some observers after removal of the thyroid are explained by the fact that in some individuals there are minute detached particles of thyroid gland lying apart from the main organ; and that after the latter has been removed these detached particles may sufficiently carry on the function of the organ in relation to the blood and the nervous system to prevent the supervention of the deleterious symptoms which usually occur after its removal. Here is, then, a notable instance of the enormous influence exerted by a 'next to nothing' upon the general organism.

Another illustration may be given from these ductless glands. It was noticed in 1849 by a celebrated physician, Dr. Addison, of Guy's Hospital, that certain cases, accompanied by extreme debility, occurring in the human subject were associated with the appearance of peculiar bronzed patches on parts of the skin and mucous membranes; and on *post-mortem* examination of these cases, which always sooner or later have a fatal termination—and indeed sooner rather than later—he found the symptoms in question to be accompanied by disease and destruction of the supra-renal capsules—small bodies which are placed close to the kidneys, but which, so far as we know, have no physiological connection with them. Now, when experiments came to be directed upon these bodies in order to elucidate their functions, and especially to observe whether their injury or removal was accompanied in animals also by symptoms similar to those occurring in man as the result of disease, it was found by Brown-Séquard that when these bodies are totally removed in any animal the removal is speedily followed by a fatal result. These experiments of Brown-Séquard's were made in 1858, and at the time attracted some attention. They were repeated by other experimenters with similar effects. But some of those who removed the supra-renal capsules obtained contrary results, and for many years the matter remained in an undecided condition. It was even supposed that the fatal results which were got by Brown-Séquard might be due to the shock of the operation or to the fact that the removal necessarily involves certain parts of the sympathetic nervous system, and were not necessarily due to the removal of the supra-renals. Recently, however, attention has been again directed to the subject, and the experiment of Brown-Séquard has been repeated by Tizzoni (1889) and by Abelous and Langlois (1891 to 1894) in various animals—viz. frogs, guinea-pigs, rabbits, and dogs. I have myself performed confirmatory experiments in monkeys. The result of all these recent observations is to show that the complete removal of the supra-renal capsules is not compatible with prolonged existence of life; and Abelous and Langlois have shown that it is accompanied by an alteration in the blood, which renders that fluid poisonous to other animals. The contrary results which have been obtained by some investigators are apparently due to the fact that in certain cases there are, as with the thyroid body, small isolated portions of supra-renal substance ('accessory capsules,' as they are sometimes called) which have not been noticed and removed at the time of the operation, and that these small portions of supra-renal substance have served to maintain that proper relation between the blood and the gland which is sufficient to prevent the supervention of the symptoms in question.

Now the weight of both supra-renal capsules taken together is not more than three drachms, and their weight, as compared with that of the whole body, is only as 1 to 6,000 or less. The accessory supra-renal capsules which may be left after the removal of the main bodies probably do not originally weigh more than one-twentieth of the whole structure, and yet this minute proportion of material (a material, so far as we know, unique in the organism) is nevertheless sufficient to maintain the composition of the blood and the nutritive equilibrium of the body, and thus to prevent the necessarily fatal result of complete removal.

Now it has been found in the case of the thyroid gland that patients in which this structure has been so diseased that its function is seriously interfered with, and animals in which it has been removed entirely, may be greatly benefited, if not indeed cured, by the inception, either subcutaneously or with food, of the thyroid glands of animals, or of the juice of such glands. Even where no affection of the thyroid can actually be detected, the exhibition of thyroid juice is frequently beneficial in certain conditions of the system; and it was noticed by Dr. Oliver, of Harrogate, that this is especially the case where there is a too-marked constriction of the blood-vessels, the juice of this body tending in such cases to reduce the extreme tone of the vascular walls, which is the cause of this condition. Encouraged by this result, Dr. Oliver was led to examine the effects of other animal extracts, and among them that of extract of supra-renal capsule. The effect of this was precisely the reverse of that which he had got with the thyroid body, for he obtained evidence tending to show that in certain cases in man extract of supra-renal capsule can produce an *increase* of vascular tone and a diminution in the size of the arteries. Beyond this point, however, Dr. Oliver was unable to proceed by clinical experiment, and he accordingly came to my laboratory with the object of determining the precise physiological effect of the active substance of the capsules. The results which were obtained show that there is present in both alcoholic and watery extracts of the gland a most potent physiological substance which when injected into the body of an animal produces, even in minute doses, a remarkable effect upon certain parts of the nervous system, upon the muscular system, upon the heart, and upon the blood-vessels. If only as much as a grain by weight of supra-renal capsule be extracted with alcohol, and if this alcoholic extract be allowed to dry, and then be redissolved in a little water or salt solution and injected into the blood of a dog, the results which are obtained, considering the minute amount of substance added to the blood, are certainly most extraordinary. The nervous centre which regulates the action of the heart is powerfully affected, so that the heart either beats very slowly and weakly, or the auricles may even for a time stop beating altogether. If, however, these inhibitory influences be cut off by division of the vagi nerves, the effect of the poison upon the heart is of an opposite character. There is great acceleration of the rate of the beat and a great increase of force. This is accompanied by a strongly marked influence upon the blood-vessels, and especially upon the arterioles. The walls of these are chiefly muscular, and the drug exerts so powerful an action upon this muscular tissue as to cause the calibre of the vessels to be almost obliterated. The heart being thus increased in force and accelerated, and the calibre of the vessels almost obliterated, the result is to raise the pressure of the blood within the arterial system to an enormous extent, so that from a blood-pressure which would be sufficient to balance a column of some four inches of mercury the pressure may rise so high as to be equal to a column of mercury of twelve or more inches.

This result is obtained, as we have seen, by a very minute dose. We have to do here with a substance which is as potent, although in a different direction, as strychnia. Whether it is a useful substance formed by the supra-renals from materials furnished by the blood, and subsequently gradually used in the economy for the virtue of its action upon the circulatory system, or whether it is to be regarded as a poison, formed by the tissues during their activity and carried by the blood to the supra-renals, there to be rendered innocuous, we do not as yet certainly know. These are important points which must form the subject of further investigation. But, however this may be, it is clear that in this gland also we again meet with an instance of the physiological importance of what Sir Frederick Bramwell called the 'next to nothing.'

I will give one more instance, taken this time from a gland which is provided with a duct. Until quite recently it might have been thought that there was nothing very obscure regarding the functions of the pancreas. The pancreas is a digestive gland which lies below and behind the stomach: it has a duct which carries its secretion into the beginning of the intestine, and that secretion acts powerfully upon all constituents of the food, digesting starch, meat, and fat. It was not supposed that the pancreas had any other function to perform. Animals can live without this secretion, and to a large extent can continue to digest and absorb their food much as before; for it has been possible to divert the secretion from the intestine and to collect it at the surface of the body; and it is found under these circumstances that, although the food is not quite so readily digested, nevertheless the animal does not materially suffer from the lack of the secretion. It was discovered, however, a few years ago (by v. Mering and Minkowski) that if, instead of merely diverting its secretion, the pancreas is bodily removed, the metabolic processes of the organism, and especially the metabolism of carbohydrates, are entirely deranged, the result being the production of permanent diabetes. But if even a very small part of the gland is left within the body, the carbohydrate metabolism remains unaltered, and there is no diabetes. The small portion of the organ which has been allowed to remain (and which need not even be left in its proper place, but may be transplanted under the skin or elsewhere) is sufficient, by the exchanges which go on between it and the blood generally, to prevent those serious consequences to the composition of the blood and the general constitution of the body which result from the complete removal of this organ. Now, some years ago it was noticed by Kühne and Sheridan Lea that, besides its proper secreting structure composed of tubular alveoli, lined by granule-containing cells, there are highly vascular patches of peculiar epithelium-like cells scattered here and there in the substance of the pancreas, which are wholly unconnected with the ducts and, so far as one can judge, with the secretion of the gland. We do not know anything whatever about the function of these patches, although from their vascularity it is extremely probable that they are not without importance physiologically, and it is tempting to conjecture that it is these cells which are specially concerned in effecting that influence upon the metabolism of carbohydrates which experiment has shown to be peculiar to the pancreas.

The lesson to be drawn from these results is clear. There is no organ of the body, however small, however seemingly unimportant, which we can presume to neglect; for it may be, as with the supra-renal capsules, the thyroid gland, and the pancreas, that the balance of assimilation and nutrition, upon the proper maintenance of which the health of the whole organism immediately depends, hinges upon the integrity of such obscure structures; and it is the maintenance of this balance which constitutes health—its disturbance, disease. Nor, on the other hand, dare we, as the investigation of the attraction-particle has shown, afford to disregard the most minute detail of structure of the body.

> 'All is concenter'd in a life intense,
> Where not a beam, nor air, nor leaf is lost,
> But hath a part of being.'

The following Papers were read:—

1. *On the Absorption of Poisons.* *By* Professor P. Heger, *Brussels.*

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2. *On a New Theory of Hearing.* *By* C. H. Hurst, *Ph.D.*

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3. *On the Fats of the Liver.* (*A preliminary Communication.*)
By D. Noel Paton.

It is pointed out that while the liver has been demonstrated to play an important part in the metabolism of carbohydrates and proteids, its possible connection with the metabolism of fats has not been investigated.

In the present series of observations an attempt is made to elucidate—

A. *The Source of Liver Fats.*

I. Are they directly stored from the fat in the food?

- *a.* Do they accumulate in the liver after a meal containing fats?
- *b.* Does the quantity of fats in the liver bear any proportion to the quantity of glycogen?

II. Are they formed from the fats in the adipose tissue of the body?

- *a.* Consideration of phosphorus poisoning.
- *b.* Relative amount of fats in liver and adipose tissue during starvation.

III. Are they formed during the katabolism of the protoplasm of liver cells?

B. *Fate of Liver Fats.*

Before investigating these points certain *preliminary observations* were necessary.

1. What is the best method of extracting the fats? Soxhlet's method was adopted.

2. How much of the ether extract is composed of true 'fats?' For saponification and estimation of the 'fatty acids' the method given by Hoppe Seyler, the method of Lebedeff, and the method of Kössel and Obermüller were tested. The last was found most satisfactory.

A large series of observations shows that the fatty acid in the ether extract varies much—from 40 to 70 per cent.—averaging about 65 per cent.

3. Is the proportion of fatty acids the same in the liver as in the ordinary fats of the body? Lebedeff's method was used. The solid acids (palmitic and stearic) are to oleic acid on an average as 1 to 1·5; in fishes, 1 to 3·5. This agrees with one or two previous estimations. In the fats of the body Lebedeff found in a lipoma 1 to 2·37, and in subcutaneous fat 1 to 5·11.

4. Is the distribution of fats uniform throughout the liver? It is found to be so.

5. In animals in the same condition is the percentage amount of fat in the liver nearly the same? Ten observations show that the variation is usually under 5 per cent., while the difference in the amount of fatty acids is even smaller.

A. *The Source of Liver Fats.*

I. Are they directly stored from the fat in the food?

a. The amount of fats in the liver at different periods after food was estimated, and, with the exception of a somewhat doubtful increase between twenty-four and thirty hours after the meal, no change in the amount of fat could be determined. Further experiments on this subject are being carried on.

b. Does the amount of fat bear any relationship to the amount of glycogen? As a result of a large number of estimations it is concluded that the fats bear no relationship to the amount of glycogen.

II. Are they formed from the fats of the adipose tissue?

a. Much of the work already published on phosphorus poisoning tends to indicate that they are so formed.

b. During starvation the amount of fats in the body falls to a much greater extent than the liver fats, which undergo a comparatively small reduction.

III. Are they formed during the katabolism of liver protoplasm?

In the *post-mortem* liver kept for several hours at 40° C. no change in the amount of fats has so far been determined. Further experiments on this point are required.

B. The fate of the liver fats has not so far been sufficiently investigated to justify any conclusions.

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4. *On the Measurement of Simple Reaction Time for Sight, Hearing, and Touch. By* Professor W. Rutherford, *M.D., F.R.S.*

Reaction time is the interval that elapses between the stimulation of a sense organ and a motor response. The physiological process involved consists of (*a*) an afferent factor—the stimulation of a sensory terminal and transmission of an impulse along sensory nerve-fibres to the brain; (*b*) a psychical factor involving an act of sensory perception and the voluntary production of a motor impulse; (*c*) an efferent factor—the transmission of an impulse along motor nerve-fibres, and muscular contraction. To render the reaction 'simple,' *discrimination* is eliminated from the act of perception by repeating the same sensation again and again without variation in its character; and *choice* is eliminated from the voluntary act by giving the same motor response again and again. In the author's experiments motor response was given by the right forefinger closing an electrical key. The stimulus for sight was the movement of a flag attached to a lever; that for hearing was a click given by transmitting an induction shock through a telephone; that for touch was an induction shock or a mechanical tap. The reaction time was ascertained by recording the moments of stimulation and of response on a revolving cylinder and also on a pendulum myograph, and measuring the interval by a tuning-fork. The pendulum myograph has not hitherto been employed in such experiments. It is very advantageous in experimenting on hearing and touch. Successive curves are superimposed, so that variations in the time of successive reactions are visible at a glance, and can be readily measured. By photography the record can be readily printed or thrown on a screen for lecture demonstrations. The reaction times, as measured by the author's methods, differ considerably from those of some German observers. In observations made on eight intelligent healthy men, varying in age from nineteen to sixty-two, the reaction time for sight varied from 0·1662 second to 0·2202 second, and was mostly between 0·20 second and 0·22 second. The reaction time for hearing varied from 0·1448 second to 0·1930 second, and was mostly between 0·15 second and 0·16 second. The reaction time for touch varied from 0·14 second to 0·1906 second in the different cases. The shortest touch reaction time is that following stimulation of the cheek: it varied from 0·141 second to 0·157 second. When the skin of a finger was stimulated the reaction time varied from 0·142 second to 0·190 second, but was mostly from 0·15 second to 0·18 second in the different cases; there was no evident relation between age and length of reaction time in the cases under observation. In a limb the reaction time is generally longer the greater the length of sensory nerve traversed by the impulse; but there may be considerable variations in the reaction times for different districts in the field of touch not explicable by difference in the length of sensory nerve traversed, but probably due to difference in the closeness of relation between centres for tactile sense in the brain and the motor centre for the hand. It may therefore happen that a response is given sooner by the hand when its skin is stimulated than when the mucous membrane of the tongue is stimulated, although in the latter case the impulse has a much shorter tract of sensory nerve to traverse. When the right hand gives the response the shortest reaction times for hearing and touch are obtained by stimulating the right ear and right side of cheek. In the experiments on sight both eyes were used at the same time. The influence of fatigue on reaction time and the remarkable restorative effect of tea were demonstrated in the photographs.

5. *On the Microscopic Appearance of Striped Muscle in Rest and in Contraction. By* Professor W. RUTHERFORD, *M.D., F.R.S.*

6. *On Effects of Suprarenal Extract.*
By Professor E. A. SCHÄFER, *F.R.S.*

7. *On Epithelial Changes produced by Irritation. By* D'ARCY POWER, *M.A., M.B. Oxon., F.R.C.S., Lecturer on Histology at the Royal Veterinary College.*

Mr. Power showed a series of preparations of the conjunctival and vaginal mucous membranes taken from rabbits and guinea-pigs which had been subjected to mechanical and chemical irritation. Many of the epithelial cells presented appearances which were identical with those described as being parasitic when they were met with in cancer. The changes in the epithelium were summarised as a general vacuolation of cells; various forms of intracellular œdema; epithelial 'pearls,' collections of leucocytes, and the spaces left after these leucocytes had migrated. These changes he had already described and figured in the 'British Medical Journal' for 1893. The series of preparations shown on the present occasion indicated that many squamous epithelial cells had the power of phagocytosis, for in no other way could the remarkable intracellular appearances be explained, and he showed cells containing a leucocyte, and others containing a microcyte. Partial necrosis of the cell also took place as a result of irritation, and there was an invasion of large eosinophile cells into the conjunctival epithelium.

The full text of the paper, with illustrations, is published in the 'Journal of Pathology and Bacteriology' for October 1894.

SATURDAY, AUGUST 11.

The following Papers were read:—

1. *On Vowel and Consonant Sounds. By* D. L. HERMANN, *Professor of Physiology in the University of Königsberg.*

2. *On an Aerotonometer and a Gas-burette.*[1]

By Professor Léon Fredericq, *Liège.*

The air which enters the lung is rich in oxygen (20·9 per cent.) and poor in carbonic acid (0·03 per cent.). On leaving the lung it is relatively poor in oxygen (18 per cent. in dogs) and rich in carbonic acid (2 to 3 per cent. in dogs). It has given up oxygen to the blood and received from it carbonic acid.

What is the cause of this gaseous exchange between the blood and the air of the pulmonary alveoli? Pflüger believed that he had succeeded in explaining this exchange by the simple laws of gaseous diffusion—laws in virtue of which each gas passes from a medium in which its tension is high towards a medium in which its tension is low. The determinations of carbonic acid tension made by Pflüger's pupils simultaneously in the blood by means of the aerotonometer and in the air of the pulmonary alveoli were in complete harmony with this explanation.

Christian Bohr has come to a different conclusion on this subject. According to him, gaseous diffusion alone does not explain the exchange of gases between the blood and the air of the lung. Bohr has found in several of his experiments the air of the alveoli richer in oxygen and poorer in carbonic acid than in the arterial blood leaving the lung. According to Bohr, the tissue of the lung plays an active part in respiration: the pulmonary epithelium excretes carbonic acid by a true secretion process, and passes oxygen into the blood, not in accordance with the laws of diffusion, but against these laws.

I have recently taken up this subject again, and in doing so have made use of the aerotonometer exhibited to the Section, which is a modification of the instrument of Pflüger. The apparatus consists essentially of a sufficiently long vertical tube, connected above with the carotid of a living animal (an anæsthetised dog), and below with a vein. The arterial blood (which has previously been rendered incoagulable by the injection of propeptone) flows continuously over the inner surface of the tube of the aerotonometer, which is kept at a temperature of 38° C. If the experiment lasts sufficient time for the attainment of equality of tension of the gases of the blood and those enclosed in the aerotonometer, an analysis of the latter gases will indicate the tension of the gases of the blood. Bohr believed that equality of tension could be reached in a few minutes, and thus obtained erroneous results. I have found that nearly two hours are necessary before equality of tension is reached. One finds then that the air of the aerotonometer contains 2 to 3 per cent. of carbonic acid and 12 to 14 per cent. of oxygen, representing the tension of these gases in the blood in accordance with the diffusion theory. I have also found that if one lets the animal breathe pure or nearly pure oxygen, the tension of this gas in the arterial blood may exceed 60 per cent. of an atmosphere. The animal, nevertheless, shows only a slight tendency to apnœa; it continues to breathe. Apnœa is thus not a necessary result of a very high oxygen tension in arterial blood. This is a fact which seems to me very important in connection with the theory of apnœa.

The gas analyses were made with a gas-burette, shown to the Section, which is simply a modification of that of Hempel. The burette is drawn out at the level where the readings are made, so as to permit of reading easily to ·02 or ·01 c.c. The confining liquid is water (and not mercury), which gives rise to scarcely any error, diffusion of gases into liquids being so slow. The carbonic acid is absorbed by potash solution, the oxygen by phosphorus.

3. *On Local Immunity. (A Preliminary Communication.)*[2]

By Louis Cobbett, *M.A., M.B., F.R.C.S., and* W. S. Melsome, *M.A., M.D,*

If it be true, as there seems reason to believe, that recovery from an infectious disease is due to certain changes in the body, which make it more resistant to the micro-organisms which cause that disease, and that the same changes are also the cause of subsequent immunity, the well-known fact that in erysipelas the parts first attacked may be recovering while the disease is spreading elsewhere would lead us to suspect that these parts have learnt to resist the streptococcus while the rest of the body is still susceptible.

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[1] For further details see *Centralblatt für Physiologie*, 1893, vii. p. 26; 1894, viii. p. 34.

[2] A full report is published in the *Journal of Pathology*, 1894.

To inquire whether erysipelas confers any such local immunity was the object of the following experiments:—

Fourteen rabbits which had recently suffered from erysipelas in the right ears were again inoculated with the streptococcus, this time in both ears. In each case a control animal, inoculated at the same time, suffered from typical erysipelas. The results were as follows: *Left ears.*—In four, only a little redness about the seat of inoculation. In four, erysipelas commenced, but aborted on the third or fourth day. In six, typical erysipelas. *Right ears.*—Inflammation rapidly appeared, affected the whole part, and subsided in twenty-four to forty-eight hours. Culture experiments, which invariably revealed the presence of streptococci in the early stages of true erysipelas, showed that micro-organisms were absent from the inflamed right ears. Thus all the right ears showed themselves to be immune, while nearly one half the left ears proved as susceptible as those of the control animals. Hence we conclude that the first attack of erysipelas had conferred a very complete local immunity. That erysipelas confers some degree of general immunity is already well known from the work of Fehleisen, Roger, and others.

Further experiments showed that this local immunity lasted only so long as any thickening remained in the ears after erysipelas. Its duration depended, therefore, on the severity of the first attack.

The inflammation which resulted from inoculations of ears previously affected we thought to be a reaction against the poisons actually introduced, and not due to the vital activity of the cocci, because we could obtain no evidence that these had multiplied and invaded the ear. This opinion was put to the test by injecting into both ears of animals, which had recently suffered from erysipelas in one ear, small quantities of concentrated filtered cultures, and in one case the streptococci themselves destroyed by heat. In these experiments a somewhat violent inflammation, of short duration (two to three days), resulted in the right ears, and a less severe but more prolonged inflammation in the left. An important difference was in the time of onset of this inflammation, which in the previously affected ears appeared many hours earlier than in the others; a difference similar to that which had already been observed to result from the inoculation of living cocci under the same conditions. Thus it appears that parts which have recently suffered from erysipelas become more quickly and intensely inflamed when subjected to the action of the products of the streptococcus than do other parts of the same animal. And when we remember that this tendency to inflammation goes hand in hand with a notably greater resistance to the living microbe, we are led to regard it as beneficial in its action, and an important factor of local immunity; an opinion in harmony with that already expressed by Metchnikoff and others—viz. that inflammation is a protective process.

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4. *A Form of Experimentally-produced Immunity.*

By J. Lorrain Smith, *M.A.*, *M.D.*, *and* E. Trevithick, *M.B.*

The occurrence of fibroid changes in the lungs when these are due to the irritant effect of inhaled dust is, according to clinical authorities, associated with increased liability of the lungs to infection by the tubercle bacillus. On the other hand, there is much clinical as well as experimental evidence to show that the condition of inflammation in the tissues is in general accompanied by an increased power of resisting the invasion of microbes.

The following experiments are brought forward to show that, in its early stages, the inflammation due to irritating dust in the pleural cavity increases the difficulty of infecting the animal in this locality with the bacillus pyocyaneus. The experiments were made on guinea-pigs and rabbits.

The dust (pounded glass) was placed in a bottle containing a quantity of water. This was sterilised, and before injection the dust was stirred up and mixed with the water. About 1·5 c.c. of this mixture was drawn into the injecting cannula. The cannula consisted of a piece of glass tubing drawn to a sharp point, with a lateral opening a short distance behind the point. This opening was made of a size just sufficient to allow the dust to pass easily through. No force was needed in the injection, the negative pressure due to the inspiratory act being sufficient to suck the moisture into the cavity.

The effects due to the simple dust were observed in several animals of both kinds. These consisted in hyperæmia of the lung with exudation of fluid and red cells into the alveolar spaces. There was also exudation of fluid into the pleural cavity in several instances, and it contained usually a considerable number of red cells also. To some extent the epithelium covering the pleural surface of the lung, was thrown off into the fluid.

The dust was rapidly absorbed into the lymphatic vessels, and could be seen, even after twelve hours, as small round yellowish patches in the pleural membrane. These when examined microscopically were found to contain large numbers of glass particles.

The injection of the bacillus pyocyaneus followed after a time, varying from one to twenty-six days.

In the following table we have a summary of the observations.

Guinea-pigs.—Six animals, with controls:—
- Two recovered completely.
- Three survived the control animals for a period.
- One was a contradictory instance, for this died sooner than the control animal.

Rabbits.—Seven animals, with controls:—
- Two recovered, the controls dying on the second day after infection.
- Three survived the controls in two cases one day, and in one case eight days.
- Two cases in which the bacillus was injected into the opposite pleural cavity. One died with the control, the other earlier.

The conclusion which is derived from these experiments is that the early stages of inflammation confer a certain amount of immunity on the pleural cavity in which the inflammation has been set up. It does not seem to vary in its protective power during the first month or so after the inflammation has been set up. In those instances where there was not complete recovery it was usually found that bacilli occurred to a much greater extent in the pleural exudation of the control animals than in that of those infected with glass dust.

The death of the last two rabbits points to the fact that probably the protection conferred is strictly localised in the inflamed tissues.

5. *On the Changes in Nerve Cells due to Functional Activity.*
By GUSTAV MANN, *M.D.*

6. *On the Effect of Gravity on the Circulation.* *By* DR. L. HILL.

7. *Experimental Inquiry upon the Different Tracts of the Central Nervous System.* *By* F. W. NUTT, *M.D.*

The origin and termination of the fibres of the fillet were investigated by noting the degeneration resulting from unilateral separation of the nuclei of Goll and Burdach from the arciform fibres issuing therefrom. The degenerated arciform fibres were traced by Marchi's method into the opposite interolivary layer, and thence into the fillet. The degenerated fibres of the fillet were followed mos distinctly into the optic thalamus, passing through the striæ medullares. They could not be traced beyond this to the cortex.

The author also gave a preliminary account of some experiments relating to the antero-lateral tract of Gowers. He considers his researches so far show that it is a crossed tract, consisting in the main of fibres proceeding to the middle lobe of the cerebellum, but also containing a few scattered fibres proceeding from the posterior roots, and apparently ending in the corpora quadrigemina.

MONDAY, AUGUST 13.

The following Papers were read:—

1. *On the Mechanical Theory of Lymph Formation.* *By* Dr. STARLING.

2. *On Lymph Formation.* *By* WALTER S. LAZARUS-BARLOW, *M.D.*

During the course of experiments performed in the Pathological Laboratory, University of Cambridge, for the investigation of the pathology of the œdema which accompanies passive congestion the author was led to examine certain of the conditions that modify the flow of lymph in the normal animal.

He introduced a cannula into one of the lymphatics of the hind limb of a dog, and, as far as possible, ligatured all remaining lymphatics. The limb was then emptied as completely as possible of lymph by rapid and firm squeezing from the paw upwards, and an observation was immediately commenced upon the amount of lymph formed in the limb during one hour. The animal was under A.C.E. mixture and was kept absolutely at rest, excepting that coagulation of the lymph in the cannula was prevented by occasional gentle squeezing of the limb. Immediately before the expiry of the hour the limb was again emptied of lymph as completely as possibly by firm squeezing. The lymph was collected in carefully graduated tubes, and the amount thus obtained was regarded as the normal for the individual.

An elastic ligature previously arranged round the limb was then tightened to such an extent as, it was known from other experiments, would raise the pressure in the femoral vein from the normal 4–5 mm. of mercury to 25–35 mm. Exactly the same processes were carried out during the collection of lymph under these modified conditions as were described for the normal conditions. The duration of increased pressure was one hour. Lastly, the elastic ligature was removed, and the amount of lymph formed in an hour under normal conditions was again estimated.

The limb was therefore as free as possible from lymph immediately before beginning and immediately before ending each of the three portions of the investigation.

The author found that the amounts collected in the three periods were either absolutely identical, or that the amount collected during the period of high venous pressure was less than that collected when the pressure was normal. On no occasion did he find that an increase of venous pressure was accompanied by an increase in the amount of lymph-flow.

The amount of lymph-flow, however, being the product of two factors—viz. the amount of fluid poured out by the blood-vessels and any modifications in that amount introduced during the sojourn of the lymph in the tissues—it was necessary before concluding that an increase of lymph-formation does not accompany an increase in venous pressure to determine whether an excessive amount of fluid had accumulated in the tissues in the form of œdema, since it was possible that the increased venous pressure might have caused an increased outflow of fluid from the capillaries and venules, and that that increased outflow might not have shown itself in an increased flow from the lymphatics, because it was in part stored up in the tissues as œdema fluid. To determine this point observations of the specific gravities of arterial blood and blood-plasma, venous blood and blood-plasma, of muscle and of skin were taken before and after the pressure in the femoral vein was raised. It was found that these underwent no changes whatever, either in the affected limb or in other parts of the body (with the exception of a rise in the specific gravity of the venous blood and blood-plasma in the affected limb) during venous obstruction, which caused a rise of pressure in the femoral vein, varying in individual cases from 48–75 mm. of mercury. The modification of specific gravity of the venous blood and blood-plasma in the affected limb manifestly depends upon its lengthened sojourn in the limb.

The author concludes, therefore, that increase of venous pressure in a limb for one hour not only does not cause an increase of lymph-flow from the lymphatics, it does not even cause an increased passage of fluid through the blood-vessel walls.

Independently, however, of the venous pressure, the amount of lymph-flow is increased when the tissues have been starved for some time or are overstocked with their own katabolic products.

The following conditions were investigated:—

1. Before and after prolonged complete anæmia (three hours), produced by an Esmarch's bandage.

2. Before and after hæmostasis, or complete cutting off of the limb, with whatever blood and lymph it might contain, from the rest of the body by means of a tight elastic bandage for one hour.

3. Before and after stimulation of the sciatic nerve, while the limb was completely anæmic and persistence *in situ* of the katabolic products, the whole lasting one hour.

All these conditions are followed by arterial dilatation in the part; and, inasmuch as arterial dilatation subsequent to section of the sciatic nerve was found by the author to be unaccompanied by any modification in the amount of lymph-flow, he concludes that the increase occurring under the conditions given above is immediately conditioned by the excessive needs of the tissues.

Under extreme conditions, such as those just given, the effect of an increase of venous pressure is markedly different from what it is when such conditions have not been introduced, for now an increase of venous pressure *is* accompanied by an increase in the lymph-flow, while the lymph-flow diminishes when the venous pressure is again allowed to return to normal. In other words, the lymph-flow now varies *directly*—the author cannot say whether it be *proportionately*—with the venous pressure. It now, therefore, bears some resemblance to mechanical filtration. Inasmuch, however, as an obstruction to the outflow of blood from the venous side itself intensifies the necessity of the tissues by damming up in them the waste products they are so anxious to get rid of, this resemblance to mechanical filtration may, after all, be only apparent.

The author concludes, therefore, that lymph-formation does not depend upon purely mechanical conditions of the circulation, but he regards it as dependent upon the needs of the tissues: those needs are, in some as yet unrecognised way, made known to the circulatory apparatus, and lead to variations in the amount of blood-flow through the part, in extreme cases active arterial dilatation of the most marked kind being induced. In such extreme cases, further, the lymph-flow varies directly with the venous pressure, and there is a resemblance to mechanical filtration; but there are reasons for supposing that this resemblance is an apparent and not a real one.

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3. *On the Innervation of the Portal Vein.*
By W. M. Bayliss *and* Dr. Starling.

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4. *On some Vaso-dilator Reflexes.* *By* W. M. Bayliss.

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5. *On the Production of Heat in Hibernating Animals.*
By Raphael Dubois, *Professor of Physiology in the University of Lyons.*

For several years the author has investigated the production of heat in the marmot in order to find out what part of the nervous system is essential for the rapid production of heat which takes place when the animal wakes up from its winter sleep.

Section of the spinal cord at the level of the fourth cervical vertebra prevents the animal from raising its temperature. Destruction of the grey substance of the brain produces a similar effect. If the section of the spinal cord be made at the level of the seventh cervical vertebra the animal grows warm slowly and incompletely; but if the operation be performed between the fourth and fifth dorsal vertebræ, then the curve of the rise of temperature presents the normal form. There is therefore a limited portion of the cord, between the fourth cervical and the first dorsal vertebræ, through which pass the centripetal or centrifugal, or both, impulses, placing the cortex of the cerebral hemispheres in communication with the rest of the organism. The pathway is through the grey substance of the spinal cord, for section of the antero-lateral or of the posterior columns does not prevent the animal from producing heat, whereas destruction of the grey matter in this limited portion of the cord produces the same effect as total section. This operation produces immediate loss of the power of movement and conscious sensibility in the greater part of the body; but the absence of the capacity to produce heat must not be attributed to this sensory and motor paralysis, for section a little lower, at the fourth dorsal vertebra, does not change the normal curve of temperature.

The section of the cord at the fourth cervical vertebra abolishes, on the one hand, the contractions of the thoracic muscles, the activity of which is very great during the rewarming and insignificant during the torpor; on the other hand, it cuts off the very important connections of the sympathetic system with the higher centres. If the cervical sympathetic be cut on both sides above the inferior cervical ganglion there is no very marked delay in the production of heat, whereas the rise of temperature is very slow and incomplete when the inferior cervical and the first thoracic ganglia are removed on both sides. These ganglia, however, are only connecting links, for the same result is obtained by section of the two splanchnic nerves or of the branches which pass directly from the abdominal sympathetics to the semilunar ganglia. Extirpation of the semilunar ganglia produces the same result as removal of the inferior cervical and first thoracic ganglia.

Experiments show that it is by acting upon the portal system that the sympathetic shares in the general process of heat production. It regulates the quantity and pressure of the blood which flows to the liver, and in this manner the production of heat in the liver and the transformation of glycogen into sugar, to be utilised for combustion when the animal awakes. The thoracic muscles become exceedingly active when the animal awakes, and thus require more glycogen or other combustible material for their contraction.

A full account of this research will shortly be published in 'Les Annales de l'Université de Lyon.'

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6. *On 'Pigeons' Milk.'* *By* E. Waymouth Reid, *Professor of Physiology in University College, Dundee.*

John Hunter (1786) discovered the fact that pigeons feed their young for some days after hatching upon a substance resembling the curd of milk, and formed in the lateral pouches of the crop of both cock and hen. This method of feeding is as yet only known in this tribe of birds.

Claude Bernard (1859) studied the nature of the substance, and found that microscopically it consisted of masses of the epithelial scales of the crop mucosa loaded with fat globules. An analysis made for Bernard by Leconte gave—

'Casein' and salts	23·23
Fat	10·47
Water	66·30

No sugar was present—a fact noted also by Hunter.

Hasse (1865) and more recently Max Teichmann (1889) have also written on the subject from the histological point of view.

The lateral pouches of the crop of the non-breeding pigeon are not glandular; the epithelium is stratified and free from fat, the submucosa provided with small vascular papillæ.

The change in the crop membrane necessary for the formation of the 'milk' commences during the incubation of the eggs, and though not visible to the naked eye till two or three days before hatching, makes itself evident by the appearance of fat-droplets in the cells ten days before this event. The main change consists in a great thickening of the epithelium, accompanied by rugose folding with reticulation, while at the same time the structure becomes enormously vascular and capillaries penetrate the epithelial layers (Hasse and Teichmann).

Small pellets of curd-like matter form in the pits of the reticulated surface, and as soon as the young are hatched these are transferred by the parents to the crops of the 'squabs,' often to the extent of 40 per cent. of the weight of the bodies of the young.

In its histological features the process of formation of the 'milk' resembles more closely that of the formation of sebum than of milk, for whole masses of fat-holding cells are cast off from the walls of the pits in the membrane; yet, unlike the sebaceous process, the nuclei of the cells persist.

Interpapillary involutions, then, of the thickened stratified epithelium of the crop act as sebaceous glands during the period of formation of the 'milk.'

This period lasts for from seven to nine days after hatching, and the maximum of activity is reached about the second day after hatching.

The young are fed almost exclusively on this substance for the first three days, though a few crushed grains are also supplied by the parents. The parents appear to crush the grains at first, though later they are supplied whole. This fact is accounted for by the condition of the gizzard membrane of the early 'squab,' for the horny secretion of the tubular glands of the mucosa takes some days to consolidate. No digestive ferments are supplied by the parents along with the 'milk,' and the proventriculus of the young 'squab' pigeon, even at twelve hours, is rich in proteolytic ferment, its glycerine extract digesting fibrin with ease. The crops of neither adult (breeding or non-breeding) nor young birds form any amylolytic or proteolytic ferment; in both cases, however, multitudes of bacteria and cocci are present, and the acidity of the contents (reaction of Uffelmann, but no reaction with phloroglucin and vanillin) is probably due to lactic fermentation. The pancreas of the 'squab' is capable of digesting starch at the time of hatching.

In the 'squab' the cell bodies of the 'milk' are dissolved off by the secretion of the proventriculus, and the fat set free in the gut is found in the cells of the villi, and also in the leucocytes of the blood. The fæces of the 'squab' are fat-free, though at an early stage they contain considerable proteid.

Though sugar is undoubtedly absent from the 'milk,' a young 'squab' pigeon before it has received any food contains sugar. In one case a triple alcoholic extract of a minced and finally pulverised 'squab' yielded over ·2 per cent. of its body weight of reducing sugar, while a subsequent triple aqueous extract gave ·16 per cent. of the body weight of an amylose yielding sugar on boiling with dilute sulphuric acid. This amylose struck no colour with iodine, and attempts to demonstrate glycogen in the bodies of unfed 'squab' pigeons have failed, though th pectoral muscles of adult birds are very rich in this substance. s in

As regards the proteids of the 'milk,' extracts with 'normal saline s as the by trituration and digestion with thymol at 40° C. show absence of -ssory. The proteoses, and peptones; presence of globulin and of caseinogen (clr with and without calcic chloride). The chief proteid, however, appears to be of the nature of nucleo-albumin (Halliburton's sodio-chloride method). Mucin is present in variable amount, and originates from the glands of the gullet below the crop. These glands enlarge and become more active during the feeding of the young.

The young pigeon is, then, fed at first upon a highly nutritious food, whose solids consist in the main of nucleo-albumin and fat. The explanation of this peculiar process lies in all probability in the fact that since pigeons rear so many broods in a season the young must be brought forward faster than could result from mere grain feeding, and hence a magnificently nutrient diet is supplied. When a cock or hen 'in milk' is separated from the young the involution of the crop changes occurs with great rapidity, for within twenty-four hours the temporary 'sebaceous glands' are loosened and cast off, the hypertrophied papillæ which lie between them being subsequently reduced. Such birds swallow their own 'milk;' their villi contain more fat than normal birds, and fatty leucocytes are seen in abundance in the blood.

Some days, however, after separation, though the gross changes in the crop membrane have disappeared, fatty cells are found in the epithelium.

The 'milk' in the crops of such separated birds is also in finer particles than normal and poorer in solid constituents.

A few quantitative analyses, kindly made for me by my colleague Mr. F. J. Hambly, are appended:—

—	A. From crop of a 4-hour 'squab' pigeon		B. From crop of a 12-hour 'squab' pigeon		C. From crop of a 51-hour 'squab' pigeon		D. From crop of hen feeding 4 'squabs' for 63 hours without aid of cock	
	% Milk	% Solids	% Milk	% Solids	% Milk	% Solids	% Milk	% Solids
Water . . .	79·33	—	77·91	—	73·98	—	84·51	—
Fat	7·74	37·4	8·15	36·9	9·32	35 8	3·99	25·8
Ash . . . } Proteids . }	12·93	62·6	1·11	5·0	1·06	4·1	·91	5·9
			12·83	58·1	15·64	60·1	10·59	68·3
—	100·00	100·00	100 00	100·0	100·00	100·0	100·00	100·0
Total solids .	20·67	—	22·09	—	26·02	—	15·49	—

7. *On the Structure of Striped Muscle.* *By* Professor J. B. HAYCRAFT.

The cross-striping of muscle is due to the form of the fibril and not to its internal structure. The fibril is like a beaded rod, and the striping is the optical expression of this. The proof of this is obtained by stamping moist collodion with a piece of muscle. The collodion stamp preserves the form of the fibrils, and shows identically the same cross-striping to the minutest detail. The stamps and their photographs were demonstrated. In one a fibril had been stamped in which one part alone was in the condition of contraction, and every detail of the striping, both in the relaxed and contracted conditions, was identically reproduced.

TUESDAY, AUGUST 14.

1. A joint meeting with Section A was held to discuss the following Papers Professor Oliver Lodge, F.R.S.

1.—*Experiments illustrating Clerk Maxwell's Theory of Light.*

– *An Electrical Theory of Vision.*

The following Papers were read:—

2. *On a Modification of Golgi's Methods.* *By* Oliver S. Strong, *of Columbia College, New York.*

Golgi's methods may be divided into two principal heads: (1) The *sublimate* method, consisting essentially of hardening in bichromate of potash followed by immersion in bichloride of mercury. This method need not be further noted here.

(2) The *silver* methods, consisting of (*a*) the long, or slow, method, consisting of hardening for about twenty to thirty days in potassium bichromate followed by immersion in a solution of silver nitrate. (*b*) The rapid method, where the hardening is done in a mixture of bichromate and osmic acid. This is the method, slightly modified, which is so extensively used, and is the method used by Ramón y Cajal. (*c*) What may be designated the mixed method, or combined method, and consists in hardening first for a few days or a week or so in potassium bichromate, then a day or two in the osmium-bichromate mixture, and finally the immersion in the silver bath.

The rapid method is the best yet discovered for work on the peripheral terminations of nerves and for the embryonic central nervous system. For adult brains it is not so well adapted owing to the poor penetration of the osmic acid, and consequent liability to overharden the periphery while the central portions of even small pieces remain untouched. Moreover, adult brains are not well adapted for the study of the nervous or axis cylinder prolongations of the cells, owing probably to their sheath, so that on such material study by these methods would be chiefly directed to the cell bodies and their protoplasmic expansions. For such purposes the long Golgi method is eminently adapted.

While the long Golgi method avoids the disadvantages, including the expense—no small consideration where such quantities are used—of osmic acid, it has the disadvantage of requiring about a month, besides the uncertainty common to all these methods.

In order to reduce this period of time, and yet to avoid the use of osmic acid, the new method here proposed for the study of adult brains is the use of *bichromate of lithium* instead of the bichromate of potassium, with the same percentages. I have found that tissues (small pieces) placed in the former reach the favourable stage of hardening for the silver impregnation in the course of one to two days, instead of twenty to thirty days. It passes through this favourable period quite rapidly, but the whole process is reduced to such a short time that it is rendered much less tedious. The pictures yielded by this process, judging from the few made thus far, are certainly fully equal to those prepared by the other methods.

The subsequent treatment is as in the other methods, *i.e.*, the piece of tissue is rinsed in strong alcohol, cut free hand or gummed on a block without any imbedding, and cut with a microtome. The sections are washed in several changes of strong alcohol, cleared in oleum origanum *Cretici*, washed briefly in xylol, and mounted in dammar or Canada balsam, thinned with xylol, without a cover slip.

It would be interesting to ascertain how well adapted this new hardening reagent would be for preparing the central nervous system for other methods of staining, *e.g.*, the Weigert method.

3. *On an Attempt to supply Motor Power to the Muscles of the Larynx from a New Source.* *By* Veterinary-Captain F. Smith, *F.R.C.V.S.*, *F.I.C.*, *Army Veterinary Department, Aldershot.*

The subject used in these observations was the horse, the inquiry having in view the possible relief of the respiratory distress so common in this animal as the result of laryngeal paralysis.

The new source of nerve supply was sought for in the spinal accessory. The recurrent and spinal accessory were exposed and divided, and the proximal end of the accessory was sutured to the distal end of the recurrent.

The only convenient test which could be employed to ascertain what progress the animal was making after the operation was that afforded by galloping it.

In one case, a few months after the above nerves had been united, there was only a slight harshness in the breathing during inspiration, even when the horse was severely 'pressed;' whereas, unless nerve impulses were passing down the accessory and through the recurrent to the larynx, the animal should have suffered from intense dyspnœa, as the whole of the dilator muscles of one side of the larynx would have been paralysed.

In a second case, the recurrent, before suture to the accessory, was known to have been degenerated for at least two years. This animal continued to have noisy breathing up to the time it was destroyed (twelve months after the operation), but it was unaccompanied by distress.

In the first case only an ordinary *post-mortem* examination was made to ascertain whether the nerves were united; in the second horse the nerves were stimulated electrically immediately after death, and a careful microscopical examination of the parts made.

On stimulating that portion of the recurrent in connection with the larynx the muscles actively responded; on stimulating the accessory well above the nodule uniting it with the recurrent, the muscles of the larynx again actively responded.

These observations were repeated several times by Professor Delépine, of Manchester (who kindly associated himself with me as an independent observer in the *post-mortem* examination), and the results are beyond doubt.

The muscles of the larynx of the above case, supplied by the accessory-recurrent nerve, were smaller and decidedly paler in colour than the healthy ones on the opposite side; on directly stimulating the muscles every portion of them actively responded to a weak current.

Professor Delépine examined the united nerves microscopically, and found in the recurrent between the point of union and the larynx small bundles of medullated nerve fibres and an amount of epi- and peri-neurium larger than normal. The place occupied by the old funiculi was quite distinct, but the nerve fibres occupied only a portion of the spaces thus indicated. The nerve fibres were all of smaller diameter than normal; most of them had a very thin myelin sheath which stained well with osmic acid. Professor Delépine was of opinion from this and the other observations that partial regeneration had certainly taken place, and that regeneration was progressing at the time of death.

By the tests employed it was not possible to say whether co-ordination of the laryngeal muscles occurred, but it is proposed in future observations to examine closely into this subject, and employ the laryngoscope to ascertain whether the impulses to the larynx are sent at the right moment.

At present it would almost appear to be possible to educate a nerve centre to perform a duty it was never intended for.

4. *On the Causes and Prevention of Suffocation in Mines.* By J. S. HALDANE, *M.A., M.D., Lecturer on Physiology, University of Oxford.*

Evidence was brought forward by the author that most of the deaths caused by colliery explosions and fires in the workings are due to suffocation, so that a thorough investigation of the subject is of great practical importance.

He concluded that poisoning by carbonic acid is never the cause of death in cases of suffocation by choke-damp, black-damp, or after-damp; that deprivation of oxygen is always the cause in the cases of choke-damp or black-damp, and usually the cause in the case of after-damp, although after-damp, even when much diluted, is sometimes poisonous from the presence in it of products of incomplete combustion, such as carbonic oxide or sulphuretted hydrogen. He also discussed the effects of white-damp, and drew attention to the exceedingly poisonous character of the gases from the explosion of blasting powder.

In conclusion he described and exhibited a portable apparatus for enabling miners to escape through an atmosphere of after-damp to the fresh air in the neighbourhood of the shafts, and for rescue purposes.

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5. *Observations on the Effects of After-damp.*
By J. SHAW LYTTLE, *M.D.*

The writer gave a detailed account of the symptoms presented by those who were found alive after the recent explosion at the Albion Steam Colliery.

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6. *Experiments on Memory.* *By* W. G. SMITH, *M.A.*, *Ph.D.*

If we examine any case of ready and accurate recollection taken from our daily experience, we find it difficult, if not impossible, to say how much of this accuracy is due to such factors as the interest which the experience aroused, the attention which we paid to it, the amount of effort and time spent during the experience. The following experiments were carried out with the view of trying to isolate experimentally the process of attention, and showing what changes in recollection occur when various kinds of distraction of attention are introduced. The experiments were begun in the Institute for Experimental Psychology in Leipzig, and have been carried on in the Physiological Laboratory in Oxford.

After a considerable number of preliminary experiments had been made, the following method was adopted. Twelve letters of the alphabet, arranged in such a manner that intelligible words or interesting ideas should not readily be suggested, were written upon a card, so as to form three lines. The card was shown to the reagent, who then tried to learn what was written on it. In each new experiment a new combination of letters was employed. By making a sufficiently large number of observations with different persons, one can eliminate to a considerable extent the fallacies arising from varying difficulty or familiarity of the combinations employed. The card was shown in every case for ten seconds, and the reagent was required, either immediately after he ceased to see the card or after an interval of about two seconds, to reproduce as much as he could remember of what he had seen.

A distinct and at the same time fairly simple form of distraction was secured by making the reagent repeat the series 2, 4, 6, 8 . . . , or more rarely 3, 6, 9 . . . , while he was learning the letters on the card. In order that the person in charge of the experiments might have an effective control over the activity of the reagent, the series had to be repeated aloud, and each step in the addition was made to coincide with the stroke of a metronome going at the rate of sixty to seventy beats per minute. In order to compare the results of this form of distraction with those gained where the vocal organ was employed, but the mental effort involved was very small, the reagent was next required while memorising to repeat aloud with each beat of the metronome an unintelligible syllable, *e.g.*, 'la.' This form of distraction was further compared with that caused by activity of another set of muscles, viz., those employed in tapping the table with the forefinger, each tap coinciding with a beat of the metronome. Lastly, experiments were carried out to show the effect of memorising without any distraction save that due to the fact that the metronome continued to beat. These four variations were given in varying order one after the other, and were so arranged that 8, 12, 16, or 20 experiments were made in one hour.

In calculating the value of the results two methods were applied. The first resembles that employed by Münsterberg ('Beiträge zur experimentellen Psychologie'), and consists in summing up the errors committed in reproducing the letters written on the card. The errors were classified as follows:—(1) Omission of a letter; (2) insertion of a wrong letter; (3) displacement of a letter or reproduction in wrong order. According to the second method, which resembles that commonly employed in estimating the value of answers to examination papers, a greater value is assigned to letters according as they correspond more exactly to what was written on the card. A letter which was given in a wrong position or without any hint as to its position had the value 1 attached to it. When a certain imperfect knowledge of its position was present, as when it was located in the right line or in the right order in a group of letters whose correct position was unknown, the value 2 was given. Each letter counted 3 when everything was correct. Letters wrongly inserted were disregarded. From an analysis of the results given by the first method it appeared that the number of insertions does not vary very much, and only in a few cases has an important influence on the results.

All the results of over five hundred experiments made with nine observers have been analysed according to the two methods, and the results agree except in a few cases.

The general conclusion is that the memory is worst when the reagent performs the simple sum in addition (1); it is better when the distraction is caused by exercise of the vocal organ (2); that caused by movement of the forefinger (3) does not make the recollection much worse than it is when the observer is not distracted at all (4). This statement holds good with only a few exceptions for every reagent, and is confirmed by the subjective observations given in reply to the questions which were frequently asked. The average of the results given by the nine persons who assisted in the experiments is as follows: the upper line gives the values according to the first method, the lower the values according to the second method of calculation—

(1)	(2)	(3)	(4)
9·7	8·7	7·95	7·4
12·9	16·3	18·5	21·2

An analysis of the errors shows that the curve of errors of omission follows closely that of the total number of errors: the other two kinds of error are much less numerous, and do not show any very important variation. A detailed analysis of the results, together with a discussion of their meaning and value, will be given in a future number of *Mind.*

7. *On Typhoid Bacilli in Water.* *By* Dr. L. Olivier.

WEDNESDAY, AUGUST 15.

The following Papers and Report were read:—

1. *On some Physiological Effects of the Passage of Rapidly-alternating Currents of great Intensity through Nerve.* *By* Professor Oliver Lodge, *F.R.S., and* Professor F. Gotch, *F.R.S.*

2. *On a New Spring Kymograph and Polyrheotome.*
By Professor T. W. W. Engelmann.

3. *On the Production with the Capillary Electrometer of Photographic Records of Currents produced by Speaking into a Telephone.* *By* G. J. Burch.

4. *Report of the Committee on the Structure and Function of the Mammalian Heart.*—See Reports, p. 464.

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CONTENTS:—Report of the Corresponding Societies Committee;—Third Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom, in co-operation with the Local Societies represented on the Association;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Fifth Report on Electrolysis in its Physical and Chemical Bearings;—Sixth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report on Molecular Phenomena associated with the Magnetisation of Iron;—Tenth Report on the Earthquake and Volcanic Phenomena of Japan;—Sixth Report on the best means of comparing and reducing Magnetic Observations;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Sixth Report of the Committee for promoting Tidal Observations in Canada;—Report on the present state of our Knowledge in Electrolysis and Electro-chemistry;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Report on the Bibliography of Spectroscopy;—Fourth Report on the Influence of Silicon on the Properties of Iron and Steel;—Second Report on the best method of establishing an International Standard for the Analysis of Iron and Steel;--Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Third Report on the present Methods of Teaching Chemistry;—Fourth Report on the Properties of Solutions;—Fourth Report on the Bibliography of Solution;—Discussion on the Theory of Solution;—Provisional Report on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report on the Absorption Spectra of Pure Compounds;—Report on the best methods for the Registration of all Type Specimens of Fossils in the British Isles;—Eighteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Sixteenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Final Report on an Ancient Sea-beach near Bridlington Quay;—Report on the Cretaceous Polyzoa;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Fourth and final Report on the 'Manure' Gravels of Wexford;—Eighth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Third Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Report on the occupation of a Table at the Zoological Station at Naples; —Report of the Committee for making a Digest of the Observations on the Migration of Birds;—Third Report on the Disappearance of Native Plants from their Local Habitats;—Fourth Report of the Committee for taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—The probable Effects on Wages of a general Reduction in the Hours of Labour;—Fourth Report on the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard;—Report on the teaching of Science in Elementary Schools;—Fourth Report as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief Forms in which the Money is employed, and the Amount annually used in the Arts;—On some new Telemeters or Range-finders;—Second Report on the Investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report on the Geography and the Habits, Customs, and Physical Characters of the Nomad Tribes of Asia Minor and Northern Persia, and on the excavation of Sites of Ancient Occupation;—Report on the Habits, Customs, Physical Characters, and Religions of the Natives of India;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries;' —Fourth Report on the Prehistoric Inhabitants of the British Islands;—Report on the Calculation of the Anthropological Measurements taken at Newcastle;—Sixth Report on the North-Western Tribes of the Dominion of Canada.

Together with the Transactions of the Sections, Sir F. A. Abel's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-FIRST MEETING, at Cardiff, August 1891, *Published at £1 4s.*

CONTENTS:—Report of the Corresponding Societies Committee;—Report on the present state of our knowledge of Thermodynamics, specially with regard to the Second Law;—Sixth Report on Electrolysis in its Physical and Chemical Bearings: —Eleventh Report on the Earthquake and Volcanic Phenomena of Japan;—Second Report of the Committee for calculating Tables of certain Mathematical Functions, and, if necessary, taking steps to carry out the Calculations, and publishing the results in an accessible form;—Fifth Report on the application of Photography to the Elucidation of Meteorological Phenomena;—Report on the Discharge of Electricity from Points;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Third (interim) Report on the various Phenomena connected with the Recalescent Points in Iron and other Metals;—Second (interim) Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report of the Committee for co-operating with Dr. C. Piazzi Smyth in his Researches on the Ultra-violet Rays of the Solar Spectrum;—Report on the best means of Comparing and Reducing Magnetic Observations;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Interim Report of the Committee for carrying on the Tables connected with the Pellian Equation from the Point where the work was left by Degen in 1817;—Seventh Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Interim Report on the Action of Light upon Dyed Colours;—Report (provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Third Report on the Bibliography of Spectroscopy;—Fifth Report on Isomeric Naphthalene Derivatives;—Fifth Report on the Bibliography of Solution;—Third Report on the best method of establishing an International Standard for the Analysis of Iron and Steel;—Provisional Report on the direct formation of Haloid Compounds from pure materials;—Report (provisional) on the Absorption Spectra of Pure Compounds;—Nineteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Registration of all the Type Specimens of British Fossils;—Seventeenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Second Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions;—Report of the Committee for working the very Fossiliferous Transition Bed between the Middle and Upper Lias in Northamptonshire, in order to obtain a more clear idea of its fauna, and to fix the position of certain species of Fossil Fish, and more fully investigate the horizon on which they occur;—Report of the Committee to complete the investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether Remains of Palæolithic Man occur in the Lower Cave Earth;—Report of the Committee for carrying on excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock-shelters at this spot;—Fourth Report on the present state of our knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Draft Report on the present state of our knowledge of the Zoology of the Sandwich Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna;—Fifth Report of the Committee for taking steps for the establishment of a Botanical Laboratory at Peradeniya, Ceylon;—Fourth Report on the Disappearance of Native Plants from their Local Habitats;—Report of the Committee for making a digest of the observations on the Migration of Birds at Lighthouses and Light-vessels, which have been carried on by the Migration Committee of the British Association;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—Report on the teaching of Science in Elementary Schools;—Third Report on the investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries;'—Seventh Report on the North-western Tribes of the Dominion of Canada;—Fifth Report on the Prehistoric Inhabitants of the British Islands;—Fourth and Final Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom in co-operation with the local societies represented on the Association;—On the Capture of Comets by Planets, especially their Capture by Jupiter;—The Recent Progress of Agriculture in India.

Together with the Transactions of the Sections, Dr. Huggins's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-SECOND MEETING, at Edinburgh, August 1892, ***Published at £1 4s.***

CONTENTS:—Report of the Corresponding Societies Committee;—Report on Meteorological Observations on Ben Nevis;—Seventh Report on Electrolysis in its Physical and Chemical Bearings;—Report on the Phenomena accompanying the Discharge of Electricity from Points;—Second Report on the Ultra-violet Rays of the Solar Spectrum;—Second Report on the Application of Photography to the Elucidation of Meteorological Phenomena;—Twelfth Report on the Earthquake and Volcanic Phenomena of Japan;—Nineteenth Report on the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Report on Electro-optics;—Eighth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on Constants and Units;—On the Application of Interference Methods to Spectroscopic Measurements;—Fourth Report on establishing an International Standard for the Analysis of Iron and Steel;—Sixth Report on Isomeric Naphthalene Derivatives;—Fourth Report on the Bibliography of Spectroscopy;—Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Report on Wave-length Tables of the Spectra of the Elements and Compounds;—Sixth Report on the Bibliography of Solution;—Sixth Report on the Nature of Solution;—Report (provisional) on the Formation of Haloids from pure Materials;—Report (provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report (provisional) on the Action of Light upon Dyed Colours;—Report on the Proximate Constituents of the various kinds of Coal;—Eighteenth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations;—Report on the Investigation of the Cave at Elbolton;—Twentieth Report on Erratic Blocks;—Third Report on the Registration of the Type Specimens of British Fossils;—Third Report on the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest;—Ninth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the Cretaceous Polyzoa;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Report on the advisability and possibility of establishing in other parts of the country observations upon the prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions;—Report on work done at the Zoological Station at Naples;—Fifth Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Second Report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and the steps taken to investigate ascertained deficiencies in the Fauna;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Sixth Report on the establishment of a Botanical Laboratory at Peradeniya, Ceylon;—Report of the Committee for making a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels;—Report on a Deep-sea Tow-net for opening and closing under Water;—Report on proposals for the Legislative Protection of Wild Birds' Eggs;—Report on the Climatological and Hydrographical Conditions of Tropical Africa;—Report on the Teaching of Science in Elementary Schools;—Second Report on the Development of Graphic Methods in Mechanical Science;—Shield Tunnelling in Loose Ground under Water Pressure, with special reference to the Vyrnwy Aqueduct Tunnel under the Mersey;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries;'—Report on the Ruins of Mashonaland and the Habits and Customs of the inhabitants;—Report on the Prehistoric and Ancient Remains of Glamorganshire;—Eighth Report on the Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada;—Report on the Habits, Customs, Physical Characteristics, and Religions of the Natives of India;—Report on the work done in the Anthropometric Laboratory.

Together with the Transactions of the Sections, Sir Archibald Geikie's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-THIRD MEETING, at Nottingham, September 1893, *Published at £*1 4*s.*

CONTENTS:—Address by the President, Professor Burdon Sanderson;—Report of the Corresponding Societies Committee;—Report on the Tables connected with the Pellian Equation from the Point where the work was left by Degen in 1817;—Interim Report on the Establishment of a National Physical Laboratory;—Interim Report on the best means of Comparing and Reducing Magnetic Observations;—Report on Electro-optics;—Report on Magnetic Work at the Falmouth Observatory;—Report on Practical Standards for Electrical Measurements;—Third Report on the Application of Photography to the Elucidation of Meteorological Phenomena;—Ninth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on the present state of our Knowledge in Electrolysis and Electrochemistry;—Thirteenth Report on the Earthquake and Volcanic Phenomena of Japan;—Interim Report on the Bibliography of Spectroscopy;—Report of the Committee for Calculating Tables of certain Mathematical Functions;—Report on Meteorological Observations on Ben Nevis;—Report on Earth Tremors;—The Action of Magnetism on Light, with a critical correlation of the various Theories of Light-propagation, by J. Larmor;—Interim Report on the Bibliography of Solution;—Report on the Action of Light upon Dyed Colours;—Seventh Report on Isomeric Naphthalene Derivatives;—Report on Wave-length Tables of the Spectra of the Elements and Compounds:—Fifth Report on establishing an International Standard for the Analysis of Iron and Steel;—Report on Solution;—Report on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Bacteriology in its Relations to Chemical Science, by Percy Frankland;—Nineteenth Report on the Circulation of Underground Waters;—Tenth Report on the Phyllopoda of the Palæozoic Rocks;—Report on the Eurypterid-bearing Deposits of the Pentland Hills;—Report on the Volcanic Phenomena of Vesuvius and its Neighbourhood;—Report on the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest in the United Kingdom;—Fourth Report on the Registration of the Type Specimens of British Fossils;—Report on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other localities;—Twenty-first Report on the Erratic Blocks of England, Wales, and Ireland;—Third Report on the present state of our Knowledge of the Zoology of the Sandwich Islands;—Interim Report of the Committee for making a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels;—Sixth Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands;—Report on the Marine Zoology of the Irish Sea;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on Investigations made at the Laboratory of the Marine Biological Association, Plymouth;—Report on the Physiological Action of the Inhalation of Oxygen in Asphyxia, more especially in Coal Mines;—Report on the Legislative Protection of Wild Birds' Eggs;—Report on the Compilation of an Index Generum et Specierum Animalium;—Report on Scottish Place-names;—Report on the Exploration of Ancient Remains in Abyssinia;—Report on the Exploration of the Glacial Region of the Karakoram Mountains;—Report on the Teaching of Science in Elementary Schools;—Interim Report on the Methods of Economic Training adopted in this and other Countries;—Report on the Climatological and Hydrographical Conditions of Tropical Africa;—Interim Report on the Dryness of Steam in Boiler Trials;—Report on the Development of Graphic Methods in Mechanical Science, by H. Hele-Shaw;—Report on the Physical Deviations from the Normal among Children in Elementary and other Schools;—First Report on the Ethnographical Survey of the United Kingdom;—Interim Report on the North-Western Tribes of Canada;—Report of the Anthropometric Laboratory Committee;—Report on Uniformity in the Spelling of Barbaric and Savage Languages and Race-names;—The Automatic Balance of Reciprocating Mechanism, by W. Worby Beaumont.

Together with the Transactions of the Sections.

The following Publications are also on sale at the Office of the Association:—

Lithographed Signatures of the Members who met at Cambridge in 1833, with the Proceedings of the Public Meetings, 4to, 4*s.*

Index to the Reports, 1831–1860, 12*s.* (carriage included).

Index to the Reports, 1861-1890, 15*s*. (carriage, 4½*d*.)

Lalande's Catalogue of Stars, £1 1*s*.

Rules of Zoological Nomenclature, 1*s*.

On the Regulation of Wages by means of Lists in the Cotton Industry:—Spinning, 2*s*.; Weaving, 1*s*.

Report on the best means for promoting Scientific Education in Schools, 6*d*.

Second Report on the present Methods of Teaching Chemistry, 1889, 6*d*.

Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements, 6*d*.

Second Report on the Development of Graphic Methods in Mechanical Science, 1892, 1*s*.

Report of the Ethnographical Survey Committee, 1893, 6*d*.

The Action of Magnetism on Light, by J. Larmor, F.R.S., 1893, 1*s*.

Table of Electro-chemical Properties of Aqueous Solutions, compiled by Rev. T. C. Fitzpatrick, 1893, 1*s*. 6*d*.

Report on Electrical Standards, with seven Appendices, 1894, 1*s*.

Report on the Present State of our Knowledge of Thermodynamics, Part II., by G. H. Bryan, with an Appendix by Prof. L. Boltzmann, 1894, 1*s*.

Report on Planimeters, by Prof. O. Henrici, F.R.S., 1894, 1*s*.

Recent Researches in the Infra-Red Spectrum, with three plates, by Dr. S. P. Langley, 1894, 2*s*.

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

LIST

OF

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CORRECTED TO SEPTEMBER 30, 1894

Office of the Association:
BURLINGTON HOUSE, LONDON, W.

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1894.

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§ indicates Annual Subscribers entitled to the Annual Report.
§§ indicates Annual Subscribers who will be entitled to the Annual Report if their Subscriptions are paid by December 31, 1894.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant General Secretary, G. Griffith, Esq.

Year of Election.

1887. *Abbe, Professor Cleveland. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, London, S.W.
1886. ‡*Abercromby, The Hon. Ralph, F.R.Met.Soc.* 21 *Chapel-Street, Belgrave-square, London, S.W.*
1891. §ABERDARE, The Right Hon. Lord, G.C.B., F.R.S., F.R.G.S. Duffryn, Mountain Ash, South Wales.
1885. *ABERDEEN, The Right Hon. the Earl of, LL.D. 37 Grosvenor-square, London, W.
1885. ‡Aberdeen, The Countess of. 37 Grosvenor-square, London, W.
1885. ‡Abernethy, David W. Ferryhill Cottage, Aberdeen.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.

Year of Election.

1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.

1873. *ABNEY, Captain W. DE W., R.E., C.B., D.C.L., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.

1880. ‡Abraham, Harry. 147 High-street, Southampton.

1877. ‡Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.

1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.

1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.

1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, London, S.W.

1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.

1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.

1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.

1894. *Acland, Harry Dyke, Old Bank, Great Malvern.

1873. *ACLAND, Sir HENRY W. D., Bart., K.C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.

1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, London, W.

1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L. Killerton, Exeter; and Athenæum Club, London, S.W.

1887. ‡ADAMI, J. G., B.A. New Museums, Cambridge.

1892. ‡Adams, David. Rockville, North Queensferry.

1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.

1876. ‡*Adams, James. 9 Royal-crescent West, Glasgow.*

1871. §Adams, John R. 2 Nutley-terrace, Hampstead, London, N.W.

1879. *ADAMS, Rev. THOMAS, M.A., D.C.L., Principal of Bishop's College, Lennoxville, Canada.

1877. ‡*Adams, William. 3 Sussex-terrace, Plymouth.*

1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Campden Hill-square, London, W.

1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic in the University of Aberdeen.

1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.

1890. ‡ADENEY, W. E., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.

1865. *Adkins, Henry. Northfield, near Birmingham.

1883. ‡Adshead, Samuel. School of Science, Macclesfield.

1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.

1887. ‡Agnew, William. Summer Hill, Pendleton, Manchester.

1884. ‡Aikins, Dr. W. T. Jarvis-street, Toronto, Canada.

1864. *Ainsworth, David, M.P. The Flosh, Cleator, Carnforth.

1871. *Ainsworth, John Stirling. Harecroft, Cumberland.

1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.

1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.

1871. §AITKEN, JOHN, F.R.S., F.R.S.E. Darroch, Falkirk, N.B.

1884. *Alabaster, H. Hazeldene, Wood-vale, Honor Oak, London, S.E.

1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.

1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.

1894. §Alexander, A. W. Blackwall Lodge, Halifax.

1891. ‡Alexander, D. T. Dynas Powis, Cardiff.

1883. ‡Alexander, George. Kildare-street Club, Dublin.

1888. *Alexander, Patrick Y. Experimental Works, Bath.

1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.

Year of Election.

1891. *Alford, Charles J., F.G.S. Coolivin, Hawkwood-road, Boscombe, Hants.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, London, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. Sydenham Cottage, Park-lane, Sheffield.
1887. *Allen, Arthur Ackland. Overbrook, Kersal, Manchester.
1879. *Allen, Rev. A. J. C. Melrose, Grange-road, Cambridge.
1887. *Allen, Charles Peter. Overbrook, Kersal, Manchester.
1888. §Allen, F. J. Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1887.§§Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1887. *Allen, Russell. 2 Parkwood, Victoria Park, Manchester.
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1863. ‡*Allhusen, C. Elswick Hall, Newcastle-on-Tyne.*
1889. §Allhusen, Frank E. Charterhouse, Godalming.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1886. ‡Allport, Samuel. 50 Whittall-street, Birmingham.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. Care of Messrs. J. Evans & Co., Bute Docks, Cardiff.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. ‡Ami, Henry. Geological Survey, Ottawa, Canada.
1885. ‡Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.
1850. ‡*Anderson, Charles William. Belvedere, Harrogate.*
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Caius College, Cambridge.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, London, S.W.
1887. ‡Anderson, Professor R. J., M.D. Queen's College, Galway.
1889. ‡Anderson, Robert Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1886. *ANDERSON, WILLIAM, D.C.L., F.R.S., M.Inst.C.E., Director-General of Ordnance Factories. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.
1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.

Year of Election.

1877. §ANGELL, JOHN, F.C.S. 5 Beacons-field, Derby-road, Fallowfield, Manchester.

1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.

1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.

1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.

Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.

1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.

1870. ‡Archer, Francis. 14 Cook-street, Liverpool.

1874. ‡ARCHER, W., F.R.S., M.R.I.A. 11 South Frederick-street, Dublin.

1894. §Archibald, A. Bank House, Ventnor.

1884. *Archibald, E. Douglas. Care of Mr. F. Tate, 28 Market-street, Melbourne.

1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S., F.R.S.E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyllshire.

1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.

1883. §Armistead, Richard. 33 Chambres-road, Southport.

1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.

1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.

1867. **Armitstead, George. Errol Park, Errol, N.B.*

1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Cragside, Rothbury.

1879. *ARMSTRONG, Sir ALEXANDER, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.

1886. ‡ARMSTRONG, GEORGE FREDERICK, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.

1873. *ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S., Pres.C.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W. 55 Granville Park, Lewisham, S.E.

1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.

1889. ‡Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.

1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.

Armstrong, Thomas. Higher Broughton, Manchester.

1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.

1893. §Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.

1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.

1853. **Arthur, Rev. William, M.A. Clapham Common, London, S.W.*

1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.

1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.

1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.

1889. §Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.

ASHTON, THOMAS, J.P. Ford Bank, Didsbury, Manchester.

1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.

1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.

*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.

1887. ‡Ashworth, Mrs. Harriet. Thorne Bank, Heaton Moor, near Stockport.

Ashworth, Henry. Turton, near Bolton.

Year of Election.
1888. *Ashworth, J. J. 39 Spring-gardens, Manchester.
1890. ‡Ashworth, J. Reginald. 20 King-street, Rochdale.
1887. ‡Ashworth, John Wallwork. Thorne Bank, Heaton Moor, near Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Birchwood-grove, Burgess Hill, Sussex.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1887. §§Atkinson, Rev. C. Chetwynd, M.A. Fairfield House, Ashton-on-Mersey.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, U.S.A.
1894. §Atkinson, George M. 28 St. Oswald's-road, London, S.W.
1894. *Atkinson, Harold W. Erwood, Beckenham, Kent.
1861. ‡Atkinson, Rev. J. A. The Vicarage, Bolton.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡ATKINSON, ROBERT WILLIAM, F.C.S. 44 Loudoun-square, Cardiff.
1894. §Atkinson, William. Erwood, Beckenham, Kent.
1863. *ATTFIELD, Professor J., M.A., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.
1860. *Austin-Gourlay, Rev. William E. C., M.A. Kincraig, Winchester.
1881. ‡*Axon, W. E. A. Fern Bank, Higher Broughton, Manchester.*
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, London, W.
1877. *AYRTON, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W.

1883. *BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
1884. ‡Baby, The Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 114 Eaton-square, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. §Baildon, H. Bellyer. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.

Year of Election.

1894. *Baily, Francis Gibson, M.A. University College, Liverpool.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James, M.P. 3 Park-terrace, Glasgow.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W., M.P. Whittinghame, Prestonkirk, Scotland.
1894. §Balfour, Henry, M.A. 11 Norham-gardens, Oxford.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R.S., F.R.S.E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1878. ‡BALL, VALENTINE, C.B., M.A., LL.D., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. §Bamford, Professor Harry, B.Sc. McGill University, Montreal, Canada.
1882. ‡Bance, Major Edward. Limewood, The Avenue, Southampton.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1894. §Barclay, Arthur. 3 Castle-street East, Oxford-street, London, W.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1887. *Barclay, Robert. Springfield, Kersal, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, London, S.E.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.
1879. *Barker, Rev. Philip C., M.A., LL.B. Boroughbridge Vicarage, Bridgwater.
1865. ‡*Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.*

Year of Election.
1870. ‡BARKLY, Sir HENRY, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1889. §Barlow, H. W. L. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1885. ‡Barlow, William, F.G.S. Hillfield, Muswell Hill, London, N.
1873. ‡BARLOW, WILLIAM HENRY, F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1881. ‡BARR, ARCHIBALD, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. 20 Victoria-terrace, Welshpool, Montgomery.
1872. *BARRETT, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *BARRINGTON, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1881.§§BARRON, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893.§§Barrow, George, F.G.S. Geological Survey Office, Edinburgh.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡BARRY, Right Rev. ALFRED, D.D., D.C.L. The Cloisters, Windsor.
1862. *BARRY, CHARLES. 1 Victoria-street, London, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, London, S.W.
1875. ‡Barry, John Wolfe, C.B., M.Inst.C.E. 23 Delahay-street, Westminster, S.W.
1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.

Year of Election.

1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1892.§§Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T., M.P. St. Margaret's House, Victoria-street, London, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893.§§Barton, Edwin H., B.Sc. University College, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1882. *BASING, The Right Hon. Lord, F.R.S. 74 St. George's-square, London, S.W.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *BASSET, A. B., M.A., F.R.S. Hedborough Hall, Holyport, Berkshire.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *BASSETT, HENRY. 26 Belitha-villas, Barnsbury, London, N.
1889. ‡BASTABLE, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8A Manchester-square, London, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E., C.M.G. Board of Trade, London, S.W.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡BATESON, WILLIAM, B.A., F.R.S. St. John's College, Cambridge.
1881. *Bather, Francis Arthur, M.A., F.G.S. 207 Harrow-road, London, W.
1836. ‡Batten, Edmund Chisholm. Thorn Falcon, near Taunton, Somerset.
1863. §BAUERMAN, H., F.G.S. 14 Cavendish-road, Balham, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892.§§Bayly, F. W. Royal Mint, London, E.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *BAYNES, ROBERT E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1887. ‡*Baynton, Alfred. 28 Gilda Brook Park, Eccles, Manchester.*
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.
Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.
1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.
1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.
1860. *BEALE, LIONEL S., M.B., F.R.S., Professor of the Principles and Practice of Medicine in King's College, London. 61 Grosvenor-street, London, W.
1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, London, S.W.
1884. ‡Beamish, G. H. M. Prison, Liverpool.

Year of Election.
1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.
1883. ‡*Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.*
1889. §Beare, Professor T. Hudson, F.R.S.E. University College, London, W.C.
1887. ‡Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.
1842. *Beatson, William. Ash Mount, Rotherham.
1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.
1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, London, W.
1886. ‡Beaugrand, M. H. Montreal.
1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.
1887. *Beaumont, W. J. Emmanuel College, Cambridge.
1885. §BEAUMONT, W. W., M.Inst.C.E., F.G.S. Melford, Palace-road, Tulse Hill, London, S.W.
1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, London, S.W.
1887. *BECKETT, JOHN HAMPDEN. Corbar Hill House, Buxton, Derbyshire.
1885. §BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London. Society's Gardens, Regent's Park, London, N.W.
1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.
1858. §Bedford, James. Woodhouse Cliff, near Leeds.
1890. ‡Bedford, James E., F.G.S. Shireoak-road, Leeds.
1891. §Bedlington, Richard. Gadlys House, Aberdare.
1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.
1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1891. *Belinfante, L. L., B.Sc., Assist.-Sec. G.S. Geological Society, Burlington House, London, W.
1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.
1873. ‡*Bell, Asahel P. 32 St. Anne's-street, Manchester.*
1871. ‡Bell, Charles B. 6 Spring-bank, Hull.
1884. ‡Bell, Charles Napier. Winnipeg, Canada.
1894. §BELL, F. JEFFREY, M.A., F.Z.S. 5 Radnor-place, Gloucester-square, London, W.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.
1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.
1875. ‡BELL, JAMES, C.B., D.Sc., Ph.D., F.R.S., F.C.S. Howell Hill Lodge, Ewell, Surrey.
1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.
1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.
1867. ‡Bell, Thomas. Belmont, Dundee.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1882. ‡*Bellingham, William. 15 Killieser-avenue, Telford Park, Streatham Hill, London, S.W.*

Year of Election.

1893. §§BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford, Cheshire.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc. University College, London, W.C.
1891. §Bennett, Alfred Rosling. 22 St. Alban's-road, Harlesden, London, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1887. ‡*Bennett, James M. St. Mungo Chemical Company, Ruckhill, Glasgow.*
1881. §Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1887. ‡Bennion, James A., M.A. 1 St. James'-square, Manchester.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon-Tyne.
1848. ‡Benson, Starling. Gloucester-place, Swansea.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Cape Town.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1885. *BENT, J. THEODORE. 13 Great Cumberland-place, London, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1894. §Berkeley, The Right Hon. the Earl of. The Heath, Boarshill, near Abingdon.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1894. §Berridge, Douglas. The Laboratory, The College, Malvern.
1887. §Berry, William. Parklands, Bowdon, Cheshire.
1870. ‡*Berwick George, M.D.* 36 *Fawcett-street, Sunderland.*
1862. ‡BESANT, WILLIAM HENRY, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1883. ‡*Bettany, Mrs.* 33 *Oakhurst-grove, East Dulwich-road, London, S.E.*
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. The Vicarage, Vowchurch, Hereford.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1890. §Bevington, Miss Mary E. Merle Wood, Sevenoaks, Kent.
1863. ‡Bewick, Thomas John, F.G.S. Suffolk House, Laurence Pountney Hill, London, E.C.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. The Zoological Station, Naples.
1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, London, S.E.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G.F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. Electric Works, Sheffield.

Year of Election

1881. ‡Binnie, Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, London, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down, near Devonport.
1888. *Birley, Miss Caroline. Seedley-terrace, Pendleton, Manchester.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1892. ‡Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.
1883. ‡Bishop, John le Marchant. 100 Mosley-street, Manchester.
1894. §Bisset, James. 5 East India-avenue, London, E.C.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889.§§Black, William. 12 Romulus-terrace, Gateshead.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. Calverley Park, Tunbridge Wells.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John S., M.A., Emeritus Professor of Greek in the University of Edinburgh. 9 Douglas-crescent, Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1863. ‡Blake, C. Carter, D.Sc. 28 Townshend-road, Regent's Park, London, N.W.
1886. ‡Blake, Dr. James. San Francisco, California.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. 43 Clifton Hill, London, N.W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, London, S.E.
1878. ‡Blakeney, Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1894. §Blakiston, Rev. C. D. Exwick Vicarage, Exeter.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Bursledon, Hants.
1887. ‡Blamires, George. Cleckheaton.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡BLANFORD, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.
1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J. The Laboratory, Citadel Hill, Plymouth.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880.§§Bloxam, G. W., M.A. 11 Presburg-street, Clapton, London, N.E.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. 73 Clarendon-road, Crumpsall, Manchester.

Year of Election.

1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. ‡Blyth, Miss Phœbe. 27 Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, London, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1881. ‡Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
1894. §Bolton, John. Clifton-road, Crouch End, London, N.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1888. ‡Boon, William. Coventry.
1893. §Boot, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, London, E.C.
1883. §Booth, James. Hazelhurst, Turton.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. ‡Booth, Rev. William H. Mount Nod-road, Streatham, London, S.W.
1883. ‡Boothroyd, Benjamin. Solihull, Birmingham.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *BOSANQUET, R. H. M., M.A., F.R.S., F.R.A.S., F.C.S. New University Club, St. James's-street, London, S.W.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §BOTHAMLEY, CHARLES H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Fernleigh, Haines Hill, Taunton, Somerset.
1867. ‡Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.
1871. *BOTTOMLEY, JAMES THOMSON, M.A., F.R.S., F.R.S.E., F.C.S. The University, Glasgow.
1884. *Bottomley, Mrs. The University, Glasgow.
1892. ‡Bottomley, W. B. Ferncliffe, Morecambe.
1876. ‡*Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.*
1890. §Boulnois, Henry Percy, M.Inst.C.E. Municipal Offices, Liverpool.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, London, S.W.
1883. ‡BOURNE, A. G., D.Sc., F.L.S., Professor of Zoology in the Presidency College, Madras.

Year of Election.

1893. §BOURNE, G. C., M.A., F.L.S. New College, Oxford.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.
1866. §BOURNE, STEPHEN, F.S.S. 5 Lansdown-road, Lee, S.E.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. ‡BOVEY, HENRY T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1881. *BOWER, F. O., D.Sc., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1886. ‡Bowlby, Rev. Canon. 101 Newhall-street, Birmingham.
1884. ‡*Bowley, Edwin. Burnt Ash Hill, Lee, Kent.*
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E., F.L.S. Ashleigh, Ashley Heath, Bowdon, Cheshire.
1887. §Box, Alfred M. 68 Huntingdon-road, Cambridge.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S., Assistant Professor of Physics in the Royal College of Science, London, S.W.
1872. *BRABROOK, E. W., F.S.A. 178 Bedford-hill, Balham, London, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1894. *Braby, Ivon. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., F.L.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, Romford, Essex.
1864. ‡BRAHAM, PHILIP, F.C.S. 3 Cobden-mansions, Stockwell-road, London, S.E.
1870. ‡Braidwood, Dr. 35 Park-road South, Birkenhead.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1879. ‡Bramley, Herbert. 6 Paradise-square, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. The Rectory, Dickleburgh.
1885. *Bratby, William, J.P. Oakfield Hale, Altrincham, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. Goldsmith-buildings, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡*Briant, T. Hampton Wick, Kingston-on-Thames.*
1886. §Bridge, T. W., M.A., Professor of Zoology in the Mason Science College, Birmingham.

Year of Election.

1870. *Bridson, Joseph R. Sawrey, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1890. ‡Brigg, W. A. Kildwick Hall, near Keighley, Yorkshire.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
1893.§§Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1893. §Briscoe, Albert E., A.R.C.Sc., B.Sc. University College, Nottingham.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡*Brittain, Frederick. Taptonville-crescent, Sheffield.*
1879. *BRITTAIN, W. H., J.P., F.R.G.S. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *BRODHURST, BERNARD EDWARD, F.R.C.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, S.W.
1865. ‡BRODIE, Rev. PETER BELLINGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1881. §Brook, Robert G. Raven-street, St. Helens, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1887. *Bros, W. Law. Sidcup, Kent.
1883. §Brotherton, E. A. Fern Cliffe, Ilkley, Yorkshire.
1886. §Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 14 Dean-street, Birmingham.
1863. *BROWN, ALEXANDER CRUM, M.D., LL.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.
1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1867. ‡Brown, Charles Gage, M.D., C.M.G. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.

Year of Election.

1883. ‡Brown, Mrs. H. Bienz. 26 Ferryhill-place, Aberdeen.

1884. ‡*Brown, Harry. University College, London, W.C.*

1883. ‡Brown, Mrs. Helen. Canaan-grove, Newbattle-terrace, Edinburgh.

1870. §BROWN, HORACE T., F.R.S., F.C.S. 52 Nevern-square, London, S.W.

Brown, Hugh. Broadstone, Ayrshire.

1883. ‡Brown, Miss Isabella Spring. Canaan-grove, Newbattle-terrace, Edinburgh.

1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.

1876. §Brown, John. Edenderry House, Newtownbreda, Belfast.

1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.

1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.

1859. ‡Brown, Rev. John Crombie, LL.D. Haddington, N.B.

1894. §Brown, J. H. 6 Cambridge-road, Brighton.

1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.

1886. §Brown R., R.N. Laurel Bank, Barnhill, Perth.

1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.

1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.

1891. §BROWN, T. FORSTER, M.Inst.C.E. Guildhall Chambers, Cardiff.

1865. ‡Brown, William. 41A New-street, Birmingham.

1885. ‡Brown, W. A. The Court House, Aberdeen.

1884. ‡Brown, William George. Ivy, Albemarle Co.. Virginia, U.S.A.

1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.

1892. ‡Browne, Harold Crichton. Crindon, Dumfries.

1879. ‡BROWNE, Sir J. CRICHTON, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-street-mansions, Victoria-street. London, S.W.

1891. §BROWNE, MONTAGU, F.G.S. Town Museum, Leicester.

1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.

1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.

1887. ‡Brownell, T. W. 6 St. James's-square, Manchester.

1865. ‡Browning, John, F.R.A.S. 63 Strand. London, W.C.

1883. ‡Browning, Oscar, M.A. King's College, Cambridge.

1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.

1892. ‡Bruce, James. 10 Hill-street, Edinburgh.

1893. §Bruce, William S. University Hall, Riddle's-court, Edinburgh.

1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.

1863. ‡Brunel, J. 21 Delahay-street, Westminster, S.W.

1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.

1868. ‡BRUNTON, T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street. London, W.

1891. ‡*Bruton, Edward Henry.* 181 *Richmond-road, Cardiff.*

1878. §Brutton, Joseph. Yeovil.

1886. *BRYAN, G. H. Thornlea, Trumpington-road, Cambridge.

1894. §Bryan, Mrs. R. P. Thornlea, Trumpington-road, Cambridge.

1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.

1894. §Brydone, R. M. Petworth, Sussex.

1890. §Bubb, Henry. Ullenwood, near Cheltenham.

1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 42 Heriot-row, Edinburgh.

1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.

1885. *Buchan, William Paton. Fairyknowe, Cambuslang, N.B.

1881. *Buchanan, John H., M.D. Sowerby, Thirsk.

1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.

Year of Election.

1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 5 Beaumont-crescent, West Kensington, London, W.
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. ‡BUCKLE, Rev. GEORGE, M.A. Wells, Somerset.
1865. *Buckley, Henry. 8 St. Mary's-road, Leamington.
1886. §Buckley, Samuel. Merlewood, Beaver-park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, London, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, London, W.C.
1869. ‡BUCKNILL, Sir J. C., M.D., F.R.S. East Cliff House, Bournemouth.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Kirton, Albemarle-road, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §Bulleid, Arthur. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, London, S.W.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.
1886. §BURBURY, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, London, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, London, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1894. §Burke, John. 77 Pembroke-road, Dublin.
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1883. ‡Burr, Percy J. 20 Little Britain, London, E.C.
1887. ‡Burroughs, Eggleston, M.D. Snow Hill-buildings, London, E.C.
1881. §Burroughs, S. M. Snow Hill-buildings, London, E.C.
1883. *Burrows, Abraham. Russell House, Rhyl, North Wales.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1894. §Burstall, H. F. W. 76 King's-road, Camden-road, London, N.W.
1891. ‡Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, London, W.
1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, London, W.
1894. §Burton, Charles V. 24 Wimpole-street, London, W.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston, Sutton Coldfield.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, London, W.
1887. *Bury, Henry. Trinity College, Cambridge.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.

Year of
Election.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. Clumber Cottage, Montague-road, Felixstowe.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth-park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1894. §Caillard, Miss E. M. Wingfield House, near Trowbridge, Wilts.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1875. ‡Caldicott, Rev. J. W., D.D. The Rectory, Shipston-on-Stour.
1886. **Caldwell, William Hay. Birnam, Chaucer-road, Cambridge.*
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. ‡CALLAWAY CHARLES, M.A., D.Sc., F.G.S. Sandon, Wellington, Shropshire.
1892.§§Calvert, A. F., F.R.G.S. The Mount, Oseney-crescent, Camden-road, London, N.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Sir Charles, Bart., M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1883. ‡*Campbell, H. J.* 81 *Kirkstall-road, Talfourd Park, Streatham Hill, London, S. W.*
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.
1894. §Capper, D. S., M.A., Professor of Mechanical Engineering in King's College, London, W.C.
1880. ‡Capper, Robert. 18 Parliament-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 18 Parliament-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, London, W.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1867. ‡Carmichael, David (Engineer). Dundee.
1876. ‡*Carmichael, Neil, M.D.* 22 *South Cumberland-street, Glasgow.*
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.

Year of Election.

1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1884. *CARPMAEL, CHARLES. Toronto, Canada.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893.§§Carr, J. Wesley. 128 Mansfield-road, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, S.W.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, Ernest H., M.A., M.B. 1 Courtfield-gardens, London, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1883. ‡*Carver, James. Garfield House, Elm-avenue, Nottingham.*
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Savile Park, Halifax.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Repton Lodge, Harborne, Birmingham.
1860. §CAYLEY, ARTHUR, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡*Chadwick, Robert. Highbank, Manchester.*
1883. ‡Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡CHAMBERS, CHARLES, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun., Assoc.M.Inst.C.E. Colába Observatory, Bombay.
*Champney, Henry Nelson. 4 New-street, York.
1881. **Champney, John E. Woodlands, Halifax.*

Year of Election.

1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. ‡Chapman, T. Algernon, M.D. Firbank, Hereford.
1874. ‡Charles, J. J., M.D., Professor of Anatomy and Physiology in Queen's College, Cork. Newmarket, Co. Cork.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A. Crichton Club, Adelphi-terrace, London, W.C.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1883. ‡*Chater, Rev. John. Part-street, Southport.*
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A.P. University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1874. *Chermside, Lieut.-Colonel H. C., R.E., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1879. *Chesterman, W. Clarkehouse-road, Sheffield.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Holywell Lodge, Oxford.
1883.§§Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1889. ‡Chirney, J. W. Morpeth.
1894. §Chisholm, G. C., M.A., B.Sc. 26 Dornton-road, Balham, London, S.W.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. The Rectory, Beaconsfield R.S.O., Bucks.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *Chree, Charles. Kew Observatory, Richmond, Surrey.
1861. ‡*Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.*
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 6 Barrow-road, Streatham Common, London, S.W.
1876. *CHRYSTAL, GEORGE, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870.§§CHURCH, A. H., M.A., F.R.S., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1867. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.

Year of Election.

1857. ‡*Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.*
1876. ‡*Clark, David R., M.A. 31 Waterloo-street, Glasgow.*
1890. ‡*Clark, E. K. 81 Caledonian-road, Leeds.*
1877. *Clark, F. J., J.P., F.L.S. Street, Somerset.
Clark, George T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. §Clark, James, M.A., Ph.D. Yorkshire College, Leeds.
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 12 Feversham-terrace, York.
1861. ‡CLARK, LATIMER, F.R.S., M.Inst.C.E. 11 Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard. Ingleside, Elm-grove, Peckham, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. §Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1861. * *Clarke, John Hope. 62 Nelson-street, Chorlton-on-Medlock, Manchester.*
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 The University, Glasgow.
1886. ‡Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1893.§§Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. 99 Waterloo-crescent, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne James. Rubislaw Den South, Aberdeen.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1891. *Coates, Henry. Pitcullen House, Perth.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Summerhill, Apperley Bridge, Leeds.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House. Milton Bridge, Edinburgh.

Year of
Election.

1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G S. Fairfield, Heaton, Bolton.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, London, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1887. ‡Cohen, Sigismund. 111 Portland-street, Manchester.
1894. *Colby, Miss E. L. Carregwen, Aberystwith.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1868. ‡*Colchester, W. P. Bassingbourn, Royston.*
1893. ‡Cole, Grenville A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1894. §Colefax, H. Arthur, Ph.D., F.C.S. 14 Chester-terrace, Chester-square, London, S.W.
1893.§§Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892. §Collet, Miss Clara E. 7 Coleridge-road, London, N.
1892. §Collie, Alexander. Harlaw House, Inverurie.
1887. ‡Collie, Norman. University College, Gower-street, London, W.C.
1887. ‡Collier, Thomas. Ashfield, Alderley Edge, Manchester.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. §Collinge, Walter E. Mason College, Birmingham.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 69 Great Russell-street, London, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 96 Great Portland-street, London, W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. 60 Heber-road, Dulwich Rise, London, S.E.
1876. ‡Collins, Sir William. 3 Park-terrace East, Glasgow.
1892. ‡Colman, H. G. Mason College, Birmingham.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.
1884. ‡Colomb, Sir J. C. R., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.
1893. §Coltman, Thomas. West End Cottage, King Richard's-road, Leicester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡COMMON, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. ‡Common, J. F. F. 21 Park-place, Cardiff.
1892. §Comyns, Frank, B.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C., M.P. Notting Hill House, Belfast.
1881. ‡CONROY, Sir JOHN, Bart., M.A., F.R.S. Balliol College, Oxford.
1893.§§Conway, W. M., M.A., F.R.G.S. 21 Clanricarde-gardens, London, W.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡COOKE, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, London, S.W.
1876. *COOKE, CONRAD W. 28 Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.

Year of Election.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1859. *Cooke, His Honour Judge, M.A., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. ‡*Cooke-Taylor, R. Whateley. Frenchwood House, Preston.*
1883. ‡*Cooke-Taylor, Mrs. Frenchwood House, Preston.*
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1888. ‡Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1883. ‡*Coomer, John. Willaston, near Nantwich.*
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1893.§§Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1838. Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1868. ‡Cooper, W. J. New Maldon, Surrey.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1884. ‡Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡COPELAND, RALPH, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1891. §Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 31 Mark-lane, London, E.C.
1894. §Corcoran, Miss Jessie R. The Chestnuts, Sutton, Surrey.
1881.§§Cordeaux, John. Great Cotes House, R.S.O., Lincoln.
1883. *Core, Professor Thomas H., M.A. Fallowfield, Manchester.
1870. *CORFIELD, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College. 19 Savile-row, London, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan. Ivy Cottage, Newcastle, Staffordshire.
1884. *Cornwallis, F. S. W. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 12 Beaufort-buildings East, Bath.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
1891. *Cotsworth, Haldane Gwilt. Moonbeam Villa, Merton-road, South Wimbledon.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. King-street, Manchester.
1874. *COTTERILL, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡COTTON, General FREDERICK C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
1879. ‡Cottrill, Gilbert I. Shepton Mallet, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1880. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, London, S.W.

Year of Election.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 31 Belsize Park-gardens, London, N.W.
1886. ‡Cowen, Mrs. G. R. 9 The Ropewalk, Nottingham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §Crabtree, William, M.Inst.C.E. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §CRAIGIE, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887.§§Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey, Cheshire.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *CRAWFORD AND BALCARRES, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough, Leicestershire.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1885. §CREAK, Captain E. W., R.N., F.R.S. 36 Kidbrooke Park-road, Blackheath, London, S.E.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡*Crombie, John. 129 Union-street, Aberdeen.*
1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡Crompton, A. 1 St. James's-square, Manchester.
1886. ‡*Crompton, Dickinson W.* 40 *Harborne-road, Edgbaston, Birmingham.*
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.

Year of Election.

1865. §**Crookes, William**, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1894. *Crosfield, Miss Margaret C. Undercroft, Reigate.
1870. *Crosfield, William, M.P. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887. §Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A. Halecote, Grange-over-Sands.
1886. ‡*Crosskey, Cecil.* 117 *Gough-road, Birmingham.*
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡*Crossley, Herbert. Ferney Green, Bowness, Ambleside.*
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1894. §Croswellor, William Thomas, F.I.Inst. Kent Lodge, Sidcup, Kent.
1894. §Crow, C. F. Home Lea, Woodstock-road, Oxford.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.
1883. ‡*Crowther, Elon. Cambridge-road, Huddersfield.*
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. ***Cunningham**, Lieut.-Colonel **Allan**, R.E., A.I.C.E. 19 Palace Gardens-terrace, Kensington, London, W.
1887. ‡Cunningham, David, M.Inst.C.E., F.R.S.E., F.S.S. Harbour-chambers, Dundee.
1877. ***Cunningham**, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1892. ‡Cunningham, Very Rev. John. St. Bernard's College, Edinburgh.
1885. ‡**Cunningham**, J. T., B.A. Scottish Marine Station, Granton, Edinburgh.
1869. ‡**Cunningham, Robert** O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. ***Cunningham**, Rev. **William**, D.D., D.Sc. Trinity College, Cambridge.
1892. ‡*Cunningham, William.* 14 *Inverleith-gardens, Edinburgh.*
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1892. §Cunningham-Craig, E. H. Clare College, Cambridge.
1885. ‡*Curphey, William S.* 15 *Bute-mansions, Hill Head, Cardiff.*
1892. *Currie, James, jun. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.

Year of Election.

1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1889. ‡Dagger, John H., F.I.C., F.C.S. Endon, Staffordshire.
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1887. ‡*Dale, Henry F., F.R.M.S., F.Z.S. Royal London Yacht Club, 2 Savile-row, London, W.*
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1894. §Dalgleish, W. Scott, M.A., LL.D. 25 Mayfield-terrace, Edinburgh.
1870. ‡DALLINGER, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, London, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡DANBY, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1894. §Darbishire, B. V., M.A., F.R.G.S. 1 Savile-row, London, W.
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡*Darling, G. Erskine. 247 West George-street, Glasgow.*
1882. ‡DARWIN, FRANCIS, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.
1881. *DARWIN, GEORGE HOWARD, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1894. §Darwin, Major Leonard, M.P. 18 Wetherby-place, South Kensington, London, S.W.
1882. ‡Darwin, W. E., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 1 Cavendish-crescent, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *DAVEY, HENRY, M.Inst.C.E. 3 Prince's-street, Westminster S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1890. ‡*Davies, Arthur. East Brow Cottage, near Whitby.*
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887. §Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1893. *Davies, Rev. T. Witton, B.A. Midland Baptist College, Nottingham.
1842. *Davies-Colley, Dr. Thomas. Newton, near Chester.*
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 13 St. Ermin's-mansions, London, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.

Year of
Election.

1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1883. ‡Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1885. *Davis, Rudolf. Almswood, Evesham.
1891. ‡Davis, W. 48 Richmond-road, Cardiff.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 373 Gillott-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Cefn Mawr Hall, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. *Dawson, Lieut.-Colonel H. P., R.A. East Holt, Alverstoke, Gosport.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S. Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, J. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, London, S.W.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 1 Fitzjohn's-avenue, London, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. 1 Obere Sophienstrasse, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893.§§Deeley, R. M. 10 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1879. ‡*De la Sala, Colonel. Sevilla House, Navarino-road, London, N.E.*
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1873. ‡Denham, Thomas, J.P. Huddersfield.
1884. ‡*Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.*
1880. §DENNY, ALFRED, F.L.S., Professor of Biology in the Firth College, Sheffield.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1874. §DE RANCE, CHARLES E., F.G.S. 55 Stoke-road, Shelton, Stoke-upon-Trent.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, London, W.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
1894. *Deverell, F. H. 13 Lawn-terrace, Blackheath, London, S.E.
1868. ‡DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.

Year of
Election.

1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, London, W.
1887. ‡DE WINTON, Colonel Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Trinity College, Cambridge.
1889. ‡Dickinson, A. H. The Wood, Maybury, Surrey.
1863. ‡Dickinson, G. T. Lily-avenue, Jesmond, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1887. §Dickson, H. N. 125 Woodstock-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1876. ‡*Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.*
1884. ‡Dix, John William H. Bristol.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, London, S.W.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne-park, London, W.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. †Dobson, G. Alkali and Ammonia Works, Cardiff.
1878. *DOBSON, G. E., M.A., M.B., F.R.S., F.L.S. Adrigole, Spring Grove, Isleworth.
1893. §Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1894. §Dockar-Drysdale, Mrs. 39 Belsize-park. London, N.W.
1875. *Docwra, George, jun. 108 London-road, Coventry.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. †Dodds, J. M. St. Peter's College. Cambridge.
1889. †Dodson, George, B.A. Downing College, Cambridge.
1893.§§Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. †Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.

Year of Election.

1877. *Donkin, Bryan, jun., M.Inst.C.E. May's Hill, Shortlands, Kent.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. South Kensington Museum, London, S.W.
1887. ‡Dorning, Elias, M.Inst.C.E., F.G.S. 41 John Dalton-street, Manchester.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. *_Douglas, Rev. G. C. M., D.D._ 18 _Royal-crescent West, Glasgow._
1877. *DOUGLASS, Sir JAMES N., F.R.S., M.Inst.C.E. Stella House, Dulwich, London, S.E.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dove, P. Edward, F.R.A.S., Sec.R.Hist.Soc. 23 Old-buildings, Lincoln's Inn, London, W.C.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1894. §Dowie, Robert Chambers. 13 Carter-street, Higher Broughton, Manchester.
1884. *Dowling, D. J. Bromley, Kent.
1857. ‡DOWNING, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, Joseph Emerson, M.Inst.C.E. 3 Great Queen-street, London, S.W.
1887. ‡Doxey, R. A. Slade House, Levenshulme, Manchester.
1894. §Doyne, R. W., F.R.C.S. 28 Beaumont-street, Oxford.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡DRESSER, HENRY E., F.Z.S. 110 Cannon-street, London, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1887. ‡Dreyfus, Dr. Daisy Mount, Victoria Park, Manchester.
1893. §DRUCE, G. CLARIDGE, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, London, W.
1856. *DUCIE, The Right. Hon. HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1867. *DUFF, The Right Hon. Sir MOUNTSTUART ELPHINSTONE GRANT-, G.C.S.I., F.R.S., F.R.G.S. York House, Twickenham.
1852. ‡DUFFERIN AND AVA, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.
1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.

Year of Election.

1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, London, W.
1881. ‡Duncombe, The Hon. Cecil. Nawton Grange, York.
1893. *Dunell, George Robert. 9 Grove Park-terrace, Chiswick, London, W.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, London, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. High School for Boys, Gateshead-on-Tyne.
1883. ‡Dunn, Mrs. Denton Grange, Gateshead-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1890. ‡*Dunsford, Follett. Rougemont Villa, Headingley, Leeds.*
1893. *Dunstan, M. J. R. 9 Hamilton-drive, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Lecturer on Chemistry at St. Thomas's Hospital and Professor of Chemistry to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1866. ‡*Duprey, Perry. Woodberry Down, Stoke Newington, London, N.*
1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1887. ‡*Dyason, John Sanford, F.R.G.S., F.R.Met.Soc. Boscobel-gardens, London, N.W.*
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Bletchley.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD, M.Inst.C.E., F.G.S. 16 Great College-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. §Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, London, E.C.
1887. *Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1870. *Eddison, John Edwin, M.D., M.R.C.S. 6 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J. Silchar, Cachar, India.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. The College House, Leamington.

Year of Election.

1887. §EDGEWORTH, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Furnival's Inn, London, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, London, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, London, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B. 1 Garden-court, Temple, London, E.C.
1867. *Edward, Allan. Farington Hall, Dundee.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. St. John's College, Oxford.
1885. *Elgar, Francis, LL.D., M.Inst.C.E., F.R.S.E. 113 Cannon-street, London, E.C.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc. Professor of Engineering in University College, Cardiff.
1864. ‡Elliott, E. B. Washington, U.S.A.
1883. *ELLIOTT, EDWIN BAILEY, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. 4 Bardwell-road, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1879. ‡Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. ‡Elliott, Thomas Henry, F.S.S. Board of Agriculture, 4 Whitehall-place, London, S.W.
1877. ‡Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1883. ‡*Ellis John. 17 Church-street, Southport.*
1880. *ELLIS, JOHN HENRY. Woodland House, Plymouth.
1891. §Ellis, Miss M. A. 2 Southwick-place, London, W.
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡ELLIS, WILLIAM HORTON. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, Sir H. W., Bart., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, George Robert. Bossington, Bournemouth.
1887. §ELWORTHY, FREDERICK T. Foxdown, Wellington, Somerset.
1870. *ELY, The Right Rev. Lord ALWYNE COMPTON, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley. Banwell Castle, Somerset.
1891. ‡Emerton, Mrs. Wolseley. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1890. ‡Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1894. §Emtage, W. T. A. University College, Nottingham.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.

Year of Election.

1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.

1869. *‡English, J. T. Wayfield House, Stratford-on-Avon.*

1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.

1860. *Enys, John Davis. Enys, Penryn, Cornwall.

1844. ‡ERICHSEN, JOHN ERIC, LL.D., F.R.S., F.R.C.S., President of, and Emeritus Professor of Surgery in, University College, London. 6 Cavendish-place, London, W.

1894. §Erskine-Murray, James R. 40 Montgomerie-drive, Glasgow.

1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.

1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College, and 13 Bradmore-road, Oxford.

1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.

1887. *Estcourt, Charles. Vyrniew House, Talbot-road, Old Trafford, Manchester.

1887. *Estcourt, P. A., F.C.S.,F.I.C. Analytical and Technological Institute, 35 Greaves-street, Oldham.

1869. ‡ETHERIDGE, ROBERT, F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, London, S.W.

1888. ‡Etheridge, Mrs. 14 Carlyle-square, London, S.W.

1883. §Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.

1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.

1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.

1889. *Evans, A. H. 9 Harvey-road, Cambridge.

1887. *Evans, Mrs. Alfred W. A. Hillside, New Mills, near Stockport, Derbyshire.

1870. *EVANS, ARTHUR JOHN, F.S.A. 33 Holywell, Oxford.

1865. *EVANS, Rev. CHARLES, M.A. 41 Lancaster-gate, London, W.

1891. ‡Evans, Franklen. Llwynarthen, Castleton, Cardiff.

1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.

1884. ‡Evans, Horace L. 6 Albert-buildings, Weston-super-Mare.

1883. *Evans, James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.

1883. *Evans, Mrs. James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.

1861. *EVANS, Sir JOHN, K.C.B., D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.

1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.

1885. **Evans, Percy Bagnall. The Spring, Kenilworth.*

1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.

1865. *Evans, William. The Spring, Kenilworth.

1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.

1886. ‡Eve, A. S. Marlborough College, Wilts.

1871. ‡Eve, H. Weston, M.A. University College, London, W.C.

1868. *EVERETT, J. D., M.A., D.C.L., F.R.S., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Derryvolgie, Belfast.

1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.

1886. ‡Everitt, William E. Finstall Park, Bromsgrove.

1883. ‡Eves, Miss Florence. Uxbridge.

1881. ‡EWART, J. COSSAR, M.D., F.R.S., Professor of Natural History in the University of Edinburgh.

1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.

1876. *EWING, JAMES ALFRED, M.A., B.Sc., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mathematics in the University of Cambridge.

Year of Election.

1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. *Eyerman, John. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡Fairley, William. Beau Desert, Rugeley, Staffordshire.
1864. ‡*Falkner, F. H. Lyncombe, Bath.*
1883. ‡Fallon, Rev. W. S 9 St. James's-square, Cheltenham.
1877. §FARADAY, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡Fards, G. Penarth.
1892. *Farmer, J. Bretland, M.A., F.L.S. Royal College of Science, London, S.W.
1886. ‡Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1882. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1886. ‡Farquharson, Colonel J., R.E. Ordnance Survey Office, Southampton.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, Ven. FREDERIC WILLIAM, M.A., D.D., F.R.S., Archdeacon of Westminster. 17 Dean's-yard, Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1886. §Felkin, Robert W., M.D., F.R.G.S. 8 Alva-street, Edinburgh.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *FELLOWS, FRANK P., K.S.J.J., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. Keswick, near Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1867. **Fergusson, H. B.* 13 *Airlie-place, Dundee.*
1883. ‡Fernald, H. P. Alma House, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.
1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡FERRIER, DAVID, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, London, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.

Year of Election.

1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *FIELD, ROGERS, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
Finch, John. Bridge Work, Chepstow.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1892. ‡Findlay, J. R., B.A. 3 Rothesay-terrace, Edinburgh.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 12 College-road, Brighton.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. 14 Dean-road, Willesden Green, London, N.W.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, J. G., M.A., LL.D. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., D.Sc., F.R.S., Professor of Natural and Experimental Philosophy, Trinity College, Dublin.
1885. *Fitzgerald, Professor Maurice, B.A. 69 Botanic-avenue, Belfast.
1894. §Fitzmaurice, M., M.Inst.C.E. Blackwall Tunnel Office, East Greenwich, London, S.E.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1888. *FITZPATRICK, Rev. THOMAS C. Christ's College, Cambridge.
1865. ‡*Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.*
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, London, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §FLETCHER, ALFRED E., F.C.S. 13 Christchurch-street, Crouch End, London, N.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 12 Trevor-square, London, S.W.
1892.§§Fletcher, George. 59 Wilson-street, Derby.
1869. ‡FLETCHER, LAVINGTON E., M.Inst.C.E. Alderley Edge, Cheshire.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, London, S.W. 36 Woodville-road, Ealing, London, W.
1862. §FLOWER, Sir WILLIAM HENRY, K.C.B., LL.D., D.C.L., D.Sc., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Departments, British Museum, South Kensington, London. 26 Stanhope-gardens, London, S.W.

Year of Election.

1889. ‡Flower, Lady. 26 Stanhope-gardens, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Helwan, Egypt.
1890. *Flux, A. W., M.A. Owens College, Manchester.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1891. §Foldvary, William. Museum Ring, 10, Buda Pesth.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, London, S.W.
1883. ‡FORBES, HENRY O., F.Z.S., Director of Museums for the Corporation of Liverpool. The Museum, Liverpool.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, H. GEORGE, F.G.S. Odsey, Ashwell, Baldock, Herts.
1883. §Formby, R. Kirklake Bank, Formby, near Liverpool.
1894. §Forrest, Frederick. Castledown, Castle Hill, Hastings.
1887. ‡FORREST, Sir JOHN, K.C.M.G., F.R.G.S. Perth, Western Australia.
1867. ‡Forster, Anthony. Finlay House, St. Leonards-on-Sea.
1883. ‡FORSYTH, A. R., M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1882.§§Forward, Henry. 10 Marine-avenue, Southend.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Sir B. Walter, M.D., M.P. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, London, N.W.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., LL.D., Sec.R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Shelford, Cambridge.
1863. ‡Foster, Robert. The Quarries, Grainger Park-road, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1888. §Fowler, Gilbert J. Dalton Hall, Manchester.
1892. §Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, London, E.C.
1876. *Fowler, John. 16 Kerrsland-street, Hillhead, Glasgow.
1882. ‡FOWLER, Sir JOHN, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. The Cedars, Warlingham, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.
1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Cleve, Wellington, Somerset.
1888. ‡Fox, Thomas. Court, Wellington, Somerset.
1886. ‡Foxwell, Arthur, M.A., M.B. 17 Temple-row, Birmingham.

Year of Election.
1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge
1880. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
1884. ‡Francis, James B. Lowell, Massachusetts, U.S.A.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, E.C.; and Manor House, Richmond, Surrey.
1845 ‡FRANKLAND, EDWARD, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry in Mason College, Birmingham.
1880. ‡Franklin, Rev. Canon. Clayton-street West, Newcastle-upon-Tyne.
1894. §Franklin, Mrs. E. L. 9 Pembridge-gardens, London, W.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1859. ‡*Fraser, George B.* 3 *Airlie-place, Dundee.*
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. 127 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042 Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. Royal Mint, London, E.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., F.R.G.S. 1 Airlie-gardens, Campden Hill, London, W.
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. The Elms, Lasswade, Midlothian.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. St. James's-chambers, Duke-street, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 13 Upper Belgrave-road, Clifton, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, GEORGE, M.Inst.C.E. 71 Lexham-gardens, Kensington, London, W.
1884. §Fuller, William, M.B. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington. Manchester.
1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡GAIRDNER, W. T., M.D., F.R.S., LL.D., Professor of Medicine in the University of Glasgow. The University, Glasgow.

Year of Election.

1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1888. ‡Gallenga, Mrs. Anna. The Falls, Chepstow.
1888. ‡Gallenga, Mrs. A. A. R. The Falls, Chepstow.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *GALTON, Sir DOUGLAS, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (PRESIDENT-ELECT and GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., D.C.L., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. New University Club, St. James's-street, London, S.W.
1870. §Gamble, Lieut.-Colonel D., C.B. St. Helens, Lancashire.
1889.§§Gamble, David, jun. St. Helens, Lancashire.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, M.A., F.L.S. Dehra Dún, North-West Provinces, India.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. Davos, Switzerland.
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1883. ‡*Gant, Major John Castle. St. Leonards.*
1887. ‡GARDINER, WALTER, M.A., F.R.S., F.L.S. Clare College, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. Fairmead, The Goffs, Eastbourne.
1894. §Gardner, J. Addyman. 5 Bath-place, Oxford.
1882. ‡GARDNER, JOHN STARKIE, F.G.S. 29 Albert Embankment, London, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1888. §Garnett, Frederick Brooksbank, C.B., F.S.S. 4 Argyll-road, Kensington, London, W.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L. London County Council, Spring-gardens, London, S.W.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §GARSON, J. G., M.D. 32 Duke-street, St. James's, London, S.W.
1894. §Garstang, Walter, M.A., F.Z.S. Lincoln College, Oxford.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragganstown, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Devanha House, Bowes-road, New Southgate, London, N.
1889. ‡Garwood, E. J. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1862. *Gatty, Charles Henry, M.A., LL.D., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. Hollydale, Hampton Wick, Middlesex.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon.
1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.

Year of Election.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. ‡Geddes, Professor Patrick. 6 James-court, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom, Jermyn-street. 10 Chester-terrace, Regent's-park, London, N.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 31 Merchiston-avenue, Edinburgh.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. Worcester College, Oxford.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1892.§§*Gibson, Francis Maitland. 1 Fingal-place, Edinburgh.*
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1892. ‡*Gibson, James. 10 North Mansion House-road, Edinburgh.*
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1885. ‡*Gibson, John, Ph.D. 15 Hartington-gardens, Edinburgh.*
1889. *Gibson, T. G. 2 Eslington-road, Newcastle-upon-Tyne.
1893.§§Gibson, Walcot, F.G.S. 28 Jermyn-street, London, S.W.
1887. ‡GIFFEN, ROBERT, C.B., LL.D., F.R.S., V.P.S.S. 44 Pembroke-road, London, S.W.
1888. *Gifford, H. J. Lyston Court, Tram Inn, Hereford.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, SIR JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. §Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 1375 Dorchester-street, Montreal, Canada.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.Inst.C.E. 26 Great George-street, London, S.W.
1878. ‡Giles, Oliver. Crescent Villas, Bromsgrove.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *GILL, DAVID, LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1888. §Gill, John Frederick. Douglas, Isle of Man.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1887. ‡Gillett, Charles Edwin. Wood Green, Banbury, Oxford.
1888. ‡Gilliland, E. T. 259 West Seventy-fourth-street, New York, U.S.A.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1892. §Gilmour, Matthew A. B. Saffronhall House, Windmill-road, Hamilton, N.B.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham, London.

Year of Election.

1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1886. *Gisborne, Hartley. Qu'Appelle Station, Assa, N.-W.T., Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1890. *Gladstone, Miss Margaret E. 17 Pembridge-square, London, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. 7 Harvey-road, Cambridge.
1881. *Gleadow, Frederic. 84 Kensington Park-road, London, W.
1859. ‡Glennie, J. S. Stuart, M.A. Verandah Cottage, Haslemere, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. ‡Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1886. ‡*Godlee, Arthur. 3 Greenfield-crescent, Edgbaston, Birmingham.*
1887. ‡Godlee, Francis. 51 Portland-street, Manchester.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1873. ‡*Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.*
1890. *GONNER, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1886. ‡*Goodman, F. B. 46 Wheeley's-road, Edgbaston, Birmingham.*
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. 1030 The Rookery Building, Chicago, Illinois, U.S.A.
1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1885. ‡Gordon, General the Hon. Sir Alexander Hamilton. 50 Queen's Gate-gardens, London, S.W.

Year of Election.

1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. 8 St. Mary-street, St. Andrews, N.B.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡Gordon, William John. 3 Lavender-gardens, London, S.W.
1865. ‡GORE, GEORGE, LL.D., F.R.S. 67 Broad-street, Birmingham.
1875. *GOTCH, FRANCIS, B.A., B.Sc., F.R.S., Professor of Physiology in University College, Liverpool. 11 Prince's Park-terrace, Liverpool.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. Lough Cutra Castle, Gort, Co. Galway, and St. Helen's, Booterstown, Co. Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1894. §Gould, G. M. 119 South 17th-street, Philadelphia, U.S.A.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1873. ‡*Gourlay, J. McMillan.* 21 *St. Andrew's-place, Bradford, Yorkshire.*
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1867. *GRAHAM, Sir CYRIL C., Bart., C.M.G., F.L.S., F.R.G.S. 8 Cheyne-walk, Chelsea, London, S.W.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1892. §Grange, C. Ernest. Royal Grammar School, Lancaster.
1893. §§Granger, F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1892. §§Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F. Northumberland-chambers, Northumberland-avenue, London, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. ‡Gray, Professor Andrew, M.A., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Canon Charles. The Vicarage, Blyth, Rotherham.
1865. ‡Gray, Charles. Swan Bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. §Gray, J. C., General Secretary of the Co-operative Union, Limited, Long Millgate, Manchester.
1892. *Gray, James H., M.A., B.Sc. The University, Glasgow.
1892. §Gray, John. 351 Clarewood-terrace, Brixton, London, S.W.
1887. §Gray, Joseph W., F.G.S. Cleveland Villa, Shurdington Road, Cheltenham.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.
*GRAY, Colonel WILLIAM. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.

Year of Election.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1883. ‡Greathead, J. H., M.Inst.C.E. 15 Victoria-street, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, London, N.W.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1889. ‡GREEN, A. H., M.A., F.R.S., F.G.S., Professor of Geology in the University of Oxford. 137 Woodstock-road, Oxford.
1888. §GREEN, JOSEPH R., M.A., B.Sc., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1887. ‡Greene, Friese. 162 Sloane-street, London, S.W.
1887. ‡Greenhalgh, Richard. 1 Temple-gardens, The Temple, London, E.C.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. ‡GREENHILL, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, London, W.C.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Driffield, near Derby.
1863. ‡Greenwell, G. E. Poynton. Cheshire.
1889. ‡*Greenwell, T. G. Woodside, Sunderland.*
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1849. ‡Greenwood, William. Stones, Todmorden.
1887. §Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1894. §Gregory, J. Walter, D.Sc. British Museum, Cromwell-road, London, S.W.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. Care of W. L. Buchanan, Esq., 212 St. Vincent-street, Glasgow.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
Griffin, S. F. Albion Tin Works, York-road, London, N.
1894. *Griffith, C. L. T. College-road, Harrow, Middlesex.
1894. *Griffith, Miss F. H. College-road, Harrow, Middlesex.
1859. *GRIFFITH, GEORGE, M.A. (ASSISTANT GENERAL SECRETARY.) College-road, Harrow, Middlesex.
1870. ‡Griffith, Rev. Henry, F.G.S. Brooklands, Isleworth, Middlesex.
1884. ‡GRIFFITHS, E. H. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.

Year of Election.
1847. ‡Griffiths, Thomas. The Elms, Harborne-road, Edgbaston, Birmingham.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1888. *Grimshaw, James Walter. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Mansfield-road, Nottingham.
1894. §Groom, P., M.A.. F.L.S. 38 Regent-street, Oxford.
1894. §Groom, T. T. The Poplars, Hereford.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY. 18 Elgin-road, St. Peter's Park, London, N.W.
1892.§§Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
GROVE, The Right Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1887. ‡GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1885. ‡Gunn, John. 4 Parkside-terrace, Edinburgh.
1891. ‡Gunn, John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, London, S.W.
1894. §Günther, R. T. Magdalen College, Oxford.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡*Guthrie, Malcolm. 2 Parkfield-road, Liverpool.*
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡GWYTHER, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1887. ‡Hackett, Henry Eugene. Hyde-road, Gorton, Manchester.
1865. ‡*Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.*
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, B.A., F.Z.S. Inisfail, Hills-road, Cambridge.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. Hecla Works, Sheffield.
1892. §Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. 27 Highfield South, Rock Ferry, Cheshire.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1887. ‡Hale, The Hon. E. J. 9 Mount-street, Manchester.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. **Hall, Miss Emily. Burlington House, Spring Grove, Isleworth, Middlesex.*
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Staverton House, Woodstock-road, Oxford.
1887. ‡Hall, John. Springbank, Leftwich, Northwich.

Year of Election.

1872. *Hall, Captain Marshall, F.G.S. Easterton Lodge, Parkstone R.S.O., Dorset.
1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *HALL, TOWNSHEND M., F.G.S. Orchard House, Pilton, Barnstaple.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §HALLIBURTON, W. D., M.D., F.R.S., Professor of Physiology in King's College, London. 9 Ridgmount-gardens, Gower-street, London, W.C.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1886. ‡*Hambleton, G. W. 23 Bryanston-street, Portman-square, London, W.*
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 1A Albyn-place, Aberdeen.
1869. ‡Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1888. *HAMMOND, ANTHONY, J.P. 10 Royal-crescent, Bath.
1851. ‡*Hammond, C. C. Lower Brook-street, Ipswich.*
1881. *Hammond, Robert. 18 Dickerson-road, Crouch End, London, N.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. 15 Pelham-grove, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, London, S.W.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, E.C.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. P. 2573 St. Catherine-street, Montreal, Canada.
1894. §Hannah, Robert, F.G.S. 82 Addison-road, London, W.
1850. ‡*Hannay, John. Montcoffer House, Aberdeen.*
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.A., M.Inst.C.E. 6 Queen Anne's-gate, London, S.W.
1886. *Hardcastle, Basil W., F.S.S. Beechenden, Hampstead, London, N.W.
1892. *Harden, Arthur, F.C.S. Ashville, Upper Chorlton-road, Manchester.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrook House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1886. ‡*Hardman, John B. St. John's, Hunter's-lane, Birmingham.*
1894. §Hardman, S. C. 225 Lord-street, Southport.
1894. §Hare, A. T., M.A. Neston Lodge, East Twickenham, Middlesex.
1894. §Hare, Mrs. Neston Lodge, East Twickenham, Middlesex.
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. †Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.

Year of Election.

1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.

1878. *Harkness, H. W., M.D. California Academy of Sciences, San Francisco, California, U.S.A.

1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London, W.C.

1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.

1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton, Sussex.

1883. *Harley, Miss Clara. The Quintic, Savile Park, Halifax, Yorkshire.

1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.

1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.

1862. *HARLEY, Rev. ROBERT, M.A., F.R.S., F.R.A.S. The Quintic, Savile Park, Halifax, Yorkshire.

1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.

1881. *HARMER, SIDNEY F., M.A., B.Sc. King's College, Cambridge.

1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.

1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.

1884. ‡Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill University, Montreal. Wallbrac-place, Montreal, Canada.

1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.

1888. ‡Harris, C. T. 4 Kilburn Priory, London, N.W.

1842. *Harris, G. W., M.Inst.C.E. Moray-place, Dunedin, New Zealand.

1889. §HARRIS, H. GRAHAM, M.Inst.C.E. 5 Great George-street, Westminster, S.W.

1884. ‡Harris, Miss Katherine E. 73 Albert Hall-mansions, Kensington-gore, London, S.W.

1888. ‡Harrison, Charles. 20 Lennox-gardens, London, S.W.

1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.

1864. ‡Harrison, George. Barnsley, Yorkshire.

1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.

1858. *HARRISON, JAMES PARK, M.A. 22 Connaught-street, Hyde Park, London, W.

1892. ‡HARRISON, JOHN. Rockville, Napier-road, Edinburgh.

1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.

1870. ‡HARRISON, REGINALD, F.R.C.S. 6 Lower Berkeley-street, Portman-square, London, W.

1853. ‡Harrison, Robert. 36 George-street, Hull.

1892. ‡Harrison, Rev. S. N. Ramsay, Isle of Man.

1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.

1885. ‡*Hart, Charles J.* 10 *Calthorpe-road, Edgbaston, Birmingham.*

1876. *Hart, Thomas. Brooklands, Blackburn.

1875. ‡Hart, W. E. Kilderry, near Londonderry.

1893. *Hartland, E. Sidney, F.S.A. Barnwood Court, Gloucester.

Hartley, James. Sunderland.

1871. ‡HARTLEY, WALTER NOEL, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.

1890. **Hartnell, Wilson.* 8 *Blenheim-terrace, Leeds.*

1886. *HARTOG, Professor M. M., D.Sc. Queen's College, Cork.

1887. §Hartog, P. J., B.Sc. Owens College, Manchester.

1885.§§Harvie-Brown, J. A. Dunipace, Larbert, N.B.

1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.

1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.

1882. ‡Haslam, George James, M.D. Owens College, Manchester.

1893. §Haslam, Lewis. Ravenswood, near Bolton, Lancashire.

Year of Election.
1875. *HASTINGS, G. W. 23 Kensington-square, London, W.
1880. ‡Hatch, Dr. F. H., F.G.S. 28 Jermyn-street, London, S.W.
1893.§§Hatton, John L. S. People's Palace, Mile End-road, London, E.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Trinity College, Dublin.
1887. *Hawkins, William. 11 Fountain-street, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 2 Down-street, W., and 33 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889.§§Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E. University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1894. §Hayes, Edward Harold. 5 Rawlinson-road, Oxford.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1888. ‡*Hazard, Rowland R. Little Mulgrave House, Hurlingham.*
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. 47 Victoria-street, Westminster, S.W.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, London, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, Manchester.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. 96 Tweedale-street, Rochdale.
1882. *Heape, Walter, M.A. St. Mary's, Trumpington, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1886. ‡Heaton, Miss Ellen. Woodhouse-square, Leeds.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *HEATON, WILLIAM H., M.A., Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1888. *Heawood, Edward, B.A., F.G.S. Skelwith Bridge, Ambleside.
1888. *Heawood, Percy Y., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.

Year of Election.

1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1882. ‡*Hedger, Philip. Cumberland-place, Southampton.*
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 92 Victoria-street, London, S.W.
1863. ‡*Hedley, Thomas. Cox Lodge, near Newcastle-upon-Tyne.*
1881. *HELE-SHAW, H. S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 20 Waverley-road, Liverpool.
1887. §Hembry, Frederick William, F.R.M.S. Sussex Lodge, Sidcup, Kent.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. 277 Lewisham High-road, London, S.E.
1883. ‡Henderson, Mrs. A. L. 277 Lewisham High-road, London, S.E.
1891. *HENDERSON, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. §§Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, London, S.W.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1892. §Henigan, Richard. Alma-road, The Avenue, Southampton.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. 81 Marlborough-road, Dublin.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Central Institution, Exhibition-road, London, S.W. 34 Clarendon-road, Notting Hill, W.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
1884. ‡Henshaw, George H. 43 Victoria-street, Montreal, Canada.
1892. ‡Hepburn, David, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Dartford, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *Herbertson, Andrew J. University Hall, Edinburgh.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool.
1893. *Herdman, Mrs. 32 Bentley-road, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham College of Science, Newcastle-upon-Tyne. Observatory House, Slough, Bucks.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1890. ‡Hewetson, H. Bendelack, M.R.C.S., F.L.S. 11 Hanover-square, Leeds.
1884. §Hewett, George Edwin. Cotswold House, St. John's Wood Park, London, N.W.
1894. §Hewins, W. A. S., M.A., F.S.S. 26 Leckford-road, Oxford.
1893. §Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.

Year of Election.

1882. ‡Heycock, Charles T., B.A. King's College, Cambridge.
1883. ‡Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. 3 Beaconsfield-villas, Dynham-road, West Hampstead, London, N.W.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1886. §HEYWOOD, HENRY, J.P., F.C.S. Witla Court, near Cardiff.
1833. *HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.
1881. §HICK, THOMAS, B.A., B.Sc. Brighton Grove, Rusholme, Manchester.
1875. ‡HICKS, HENRY, M.D., F.R.S., F.G.S. Hendon Grove, Hendon, Middlesex, N.W.
1877. §HICKS, Professor W. M., M.A., D.Sc., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.
1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *HICKSON, SYDNEY J., M.A., D.Sc., Professor of Zoology in Owens College, Manchester.
1864. *HIERN, W. P., M.A. Castle House, Barnstaple.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 5 Trebovir-road, Earl's Court, London, S.W.
1891. §Higgs, Henry, LL.B., F.S.S. 164 Brixton Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1894. §Hill, Rev. A. Du Boulay. The Vicarage, Downton, Wilts.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathly, East Grinstead.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *HILL, Rev. EDWIN, M.A., F.G.S. The Rectory, Cockfield, R.S.O., Suffolk.
1887. ‡Hill, G. H. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1886. ‡HILL, M. J. M., M.A., D.Sc., F.R.S., Professor of Pure Mathematics in University College, London.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *HILLHOUSE, WILLIAM, M.A., F.L.S., Professor of Botany in Mason Science College, Birmingham. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡HINDE, G. J., Ph.D., F.G.S. Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Sir Benjamin, Bart., M.P. Hatherton Lodge, Cradley, Worcestershire.

Year of Election.

1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1890. *Hirst, James Andus. Adel Tower, Leeds.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1884. ‡Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. Livingstone House, 374 Wandsworth-road London, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1887. *Hobson, Bernard, B.Sc. Tapton Elms, Sheffield.
1883. ‡Hobson, Mrs. Carey. 5 Beaumont-crescent, West Kensington, London, W.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, London, S.E.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1894. §Hogg, A. F. 134 Birchanger-road, South Norwood, London, S.E.
1894. §Holah, Ernest. 5 Crown-court, Cheapside, London, E.C.
1854. *Holcroft, George. Tyddyngwladis, Ganllwyd, near Dolgelly, North Wales.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Sir Isaac, Bart., M.P. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. §Holgate, Benjamin, F.G.S. Cardigan Villa, Grove-lane, Headingley, Leeds.
1879. ‡Holland, Calvert Bernard. Hazel Villa, Thicket-road, Anerley, London, S.E.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1889. §§Holländer, Bernard. King's College, Strand, London, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth, Middlesex.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 59 London-road, Derby.
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1889. ‡*Holmes, Ralph, B.A. Hulme Grammar School, Manchester.*

Year of Election.

1882. *HOLMES, THOMAS VINCENT, F.G.S. 28 Croom's-hill, Greenwich, S.E.

1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.

1875. *Hood, John. Chesterton, Cirencester.

1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.

1892. §Hooker, Reginald H., B.A. Royal Statistical Society, 9 Adelphi-terrace, London, W.C.

1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.

1877. *Hooper, Rev. Samuel F., M.A. The Vicarage, Blackheath Hill, Greenwich, S.E.

1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.

1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, London, W.

1884. *Hopkins, Edward M. Orchard Dene, Henley-on-Thames.

1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.

1884. *HOPKINSON, CHARLES. The Limes, Didsbury, near Manchester.

1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.

1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.

1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, London, W.; and The Grange, St. Albans.

1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.

1891. ‡Horder, T. Garrett. 10 Windsor-place, Cardiff.

Hornby, Hugh. Sandown, Liverpool.

1886. ‡*Horne, Edward H. Innisfail, Beulah Hill, Norwood, S.E.*

1885. ‡HORNE, JOHN, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.

1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.

1884. *Horsfall, Richard. Stoodley House, Halifax.

1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.

1892. ‡*Horsley, Reginald E., M.B.* 46 *Heriot-row, Edinburgh.*

1893. *HORSLEY, VICTOR A. H., B.Sc., F.R.S., F.R.C.S., Professor of Pathology in University College, London. 25 Cavendish-square, London, W.

1884. *Hotblack, G. S. Prince of Wales-road, Norwich.

1868. ‡*Hotson, W. C. Upper King-street, Norwich.*

1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.

1886. ‡Houghton, F. T. S., M.A. 119 Gough-road, Edgbaston, Birmingham.

1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.

1884. ‡Houston, William. Legislative Library, Toronto, Canada.

1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.

Hovenden, W. F., M.A. Bath.

1893. §Howard, F. T., B.A., F.G.S. University College, Cardiff.

1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.

1886. *Howard, James L., D.Sc. 86 St. John's-road, Waterloo, near Liverpool.

1887. *Howard, S. S. Bayfield, Beckenham, Kent.

1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.

1886. ‡Howatt, David. 3 Birmingham-road, Dudley.

1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.

1885. ‡Howden, James C., M.D. Sunnyside, Montrose, N.B.

1889. §Howden, Robert, M.B. University of Durham College of Medicine, Newcastle-upon-Tyne.

1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Great Britain. Geological Survey Office, Edinburgh.

Year of Election.

1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1891. §Howell, Rev. William Charles, M.A., Vicar of Holy Trinity, High Cross, Tottenham, Middlesex.
1886.§§HOWES, Professor G. B., F.L.S. Royal College of Science, South Kensington, London, S.W.
1884. ‡Howland, Edward P., M.D. 211 4½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., M.P., F.R.S., F.S.A. Bentcliffe, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §HOYLE, WILLIAM E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1888. ‡HUDSON, C. T., M.A., LL.D., F.R.S. 2 Barton-crescent, Dawlish.
1894. §Hudson, John E. 334 Marlborough-street, Boston, Massachusetts, U.S.A.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, London, S.W.
1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse Hill, Brixton, London, S.W.
1892. ‡*Hughes, Alfred W. Woodside, Musselburgh.*
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1891.§§Hughes, Thomas. 31 Loudoun-square, Cardiff.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1891.§§Hughes, Rev. W. Hawker. Jesus College, Oxford.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡HULKE, JOHN WHITAKER, F.R.S., F.R.C.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1887. *HUMMEL, Professor J. J. 152 Woolsley-road, Leeds.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, London, S.W.
1884. *Humphreys, A. W. 50 Broadway, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1862. *HUMPHRY, Sir GEORGE MURRAY, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.

Year of Election

1865. ‡*Hunt, J. P. Gospel Oak Works, Tipton.*
1864. ‡*Hunt, W. Folkestone.*
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1869. *Hunter, Rev. Robert. LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. ‡*Hurst, Walter, B.Sc. West Lodge, Todmorden.*
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1894. *Hutchinson, A. Pembroke College, Cambridge.
1876. ‡*Hutchinson, John. 22 Hamilton Park-terrace, Glasgow.*
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡*Hutton, Henry D. 17 Palmerston-road, Dublin.*
1887. *Hutton, J. Arthur. 29 Dale-street, Manchester.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, The Right Hon. THOMAS HENRY, Ph.D., LL.D., D.C.L., F.R.S., F.L.S., F.G.S., Hon. Professor of Biology in the Royal College of Science, London. Hodeslea, Eastbourne.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1883.§§Idris, T. H. W. 58 Lady Margaret-road, London, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 7 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. §Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1892.§§Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882.§§IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill, Bishop Stortford, Herts.

Year of Election.

1888. *Isaac, J. F. V., B.A. 114 Marine-parade, Brighton.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1891. *Ismay, Thomas H. 10 Water-street, Liverpool.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *JACKSON, Professor A. H., B.Sc., F.C.S. 358 Collins-street, Melbourne, Australia.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. 1 Morley-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Lyme Regis, Dorset.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1869. §Jackson, Moses, J.P. Lansdowne House, Tonbridge.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. 38 Prom. des Anglais, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. 6 New-court, Lincoln's Inn, London, W.C.
1872. ‡*James, Christopher. 8 Laurence Pountney-hill, London, E.C.*
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, London, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1858. ‡James, William C. Woodside, Plymouth.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, London, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., LL.D., F.R.S., F.C.S., Professor of Chemistry in the University of Aberdeen.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡*Jasper, Henry. Holmedale, New Park-road, Clapham Park, London, S.W.*
1886. §Jeffcock, Rev. Prebendary John Thomas, F.S.A. The Rectory, Wolverhampton.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1867. ‡Jeffreys, Howel, M.A. 61 Bedford-gardens, Kensington, London, W.

Year of Election.

1885. ‡Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.

1887. §**JEFFS, OSMUND W.** 92 Westbourne-street, Liverpool.

1881. ‡**JELLICOE, C. W. A.** Southampton.

1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.

1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.

1880. ***JENKINS, Sir JOHN JONES.** The Grange, Swansea.

1891. ‡Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. 17 St. Julian's-road, Kilburn, London, N.W.

1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.

1893. §Jennings, G. E. Ash Leigh-road, Leicester.

1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.

Jessop, William, jun. Overton Hall, Ashover, Chesterfield.

1889. ‡Jevons, F. B., M.A. The Castle, Durham.

1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.

1891. ‡John, E. Cowbridge, Cardiff.

1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.

1884. §**JOHNSON, ALEXANDER**, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.

1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.

1883. ‡Johnson, Ben. Micklegate, York.

1871. *Johnson, David, F.C.S., F.G.S. 11 Thurlow-terrace, Larkhall Rise, Clapham, London, S.W.

1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.

1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.

1888. ‡Johnson, J. G. Southwood Court, Highgate, London, N.

1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.

1872. ‡Johnson, J. T. 27 Dale-street, Manchester.

1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.

1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.

1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.

1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.

1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.

1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.

1883. ‡Johnson, William. Harewood, Roe-lane, Southport.

1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.

1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.

1859. ‡Johnston, James. Newmill, Elgin, N.B.

1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.

1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.

1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.

1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.

1884. *Johnston, W. H. 6 Latham-street, Preston, Lancashire.

1885. ‡**JOHNSTON-LAVIS, H. J.**, M.D., F.G.S. Palazzo Caramanico, Chiatcmone, Naples.

1886. ‡Johnstone, G. H. Northampton-street, Birmingham.

1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.

1864. ‡Jolly, Thomas. Park View-villas, Bath.

1871. ‡**JOLLY, WILLIAM**, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.

1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.

1888. ‡**JOLY, JOHN**, M.A., D.Sc., F.R.S. 39 Waterloo-road, Dublin.

Year of Election.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1849. ‡Jones, Baynham. Walmer House, Cheltenham.
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools. 7 Marine-terrace, Aberystwith.
1891. ‡Jones, D. Edgar, M.D. Spring Bank, Queen-street, Cardiff.
1890. §Jones, Rev. Edward, F.G.S. Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1891. ‡*Jones, Evan Rowland. Bonnyrigg, Penarth.*
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *JONES, Rev. G. HARTWELL, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. 5 Cook-street, Liverpool.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, London, N.W.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, London, S.W.
1893.§§*Jones, Professor J. E , B.Sc. Ellenslea,* 70 *Lichfield-road, Stafford.*
1881. *JONES, J. VIRIAMU, M.A., B.Sc., F.R.S., Principal of the University College of South Wales and Monmouthshire, Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡Jones, William Lester. 22 Newport-road, Cardiff.
1875. *Jose, J. E. 29 Cressington Park, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1875. *Joule, Benjamin St. John B., J.P. Rothesay, N.B.
1870. ‡Jowitt, A. Scotia Works, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. West Hanney, Wantage, Berkshire.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡JUDD, JOHN WESLEY, F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 16 Cumberland-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, London, N.
1888.§§Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. 31 Parliament-street, London, S.W.
1887. ‡Kay, Miss. Hamerlaund, Broughton Park, Manchester.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
1883. ‡*Kearne, John H. Westcliffe-road Birkdale, Southport.*
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.

Year of Election.

1894 §Keene, Captain C. T. P., F.L.S., F.Z.S., F.S.S. 11 Queen's-gate, London, S.W.
1894. §Keightley, Rev. G. W. Great Stambridge Rectory, Rochford, Essex.
1892. ‡Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.
1887. ‡Kellas-Johnstone, J. F. 35 Crescent, Salford.
1884. ‡Kellogg, J. H., M.D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1885. §Keltie, J. Scott, Assist.Sec.R.G.S., F.S.S. 1 Savile-row, London, W.
1847. *KELVIN, The Right Hon. Lord, M.A., LL.D., D.C.L., Pres.R.S., F.R.S.E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.
1887.§§Kemp, Harry. 254 Stretford-road, Manchester.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Kildare, Arundel-road, Eastbourne.
1891. §KENDALL, PERCY F., F.G.S. Yorkshire College, Leeds.
1875. ‡KENNEDY, ALEXANDER B. W., F.R.S., M.Inst.C.E., Emeritus Professor of Engineering in University College, London. 2 Gloucester-place, Portman-square, London, W.
1884. ‡Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §Kent, A. F. Stanley. St. Thomas's Hospital, London, S.E.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1886. §KENWARD, JAMES, F.S.A. 280 Hagley-road, Birmingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.
1892. §Kerr, J. Graham. Christ's College, Cambridge.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡KERR, REV. JOHN, LL.D., F.R.S. Free Church Training College, Glasgow.
1889. ‡Kerry, W. H. R. Wheatlands, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Rose Villa, Vale-road, Bowdon, Cheshire.
1869. *Kesselmeyer, William Johannes. Rose Villa, Vale-road, Bowdon, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §KIDSTON, ROBERT, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1890.§§Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡KINAHAN, G. HENRY, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. *KINCH, EDWARD, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.

Year of Election.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Wainsford, Lymington, Hants.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. 6 Wedderburn-road, Hampstead, London, N.W.
1860. *King, Mervyn Kersteman. 3 Clifton-park, Clifton, Bristol.
1875. *King, Percy L. 2 Worcester-avenue, Clifton, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. §King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1875. §KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst, Kent.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Fernroyd, St. Margaret's-road, Bowdon, Cheshire.
1875. ‡*Kirsop, John. 6 Queen's-crescent, Glasgow.*
1883. ‡*Kirsop, Mrs. 6 Queen's-crescent, Glasgow.*
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. M. Bushwood, Wanstead, Essex.
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 42 Upper Gray-street, Edinburgh.
1887. *Knott, Herbert. Wharf Street Mills, Ashton-under-Lyne.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
*Knox, George James. 27 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P., M.A. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1892.§§Kohn, Dr. Charles A. University College, Liverpool.
1890. *Krauss, John Samuel, B.A. Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., Union-square, New York City, U.S.A.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡*Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.*

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 1 Elm-court, Temple, London, E.C.
1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1877. ‡Lake, W. C., M.D., F.R.G.S. Teignmouth.

Year of Election.

1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Old Lodge, Salisbury.
1887. ‡LAMB, HORACE, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. Burton-road, Didsbury, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, S.E.
1893.§§Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893.§§Lamplugh, G. W., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, London, S.E.
1883. ‡Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *LANGLEY, J. N., M.A., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 2 Bradmore-road, Oxford.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P., M.A. The Moat, Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. Catesby House, Manor-road, Barnet, Herts.
1891. ‡Laurie, A. P. 49 Beaumont-square, London, E.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, London, E.C.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S. King's College, Cambridge.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. Fenny Royd Hall, Hipperholme, Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1889. §Laws, W. G., M.Inst.C.E. 5 Winchester-terrace, Newcastle-upon-Tyne.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.
1868. *Lawson, M. Alexander, M.A., F.L.S. Ootâcamund, Bombay.
1853. ‡*Lawton, William. 5 Victoria-terrace, Derringham, Hull.*
1888. §Layard, Miss Nina F. 1 Park-place, Fonnereau-road, Ipswich.

Year of
Election.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1883. §Leach, John. Claremont, Levenshulme, Manchester.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, London, S.W.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. 6 Sussex-place, Regent's Park, London, N.W.
1894. *Leahy, A. H., M.A., Professor of Mathematics in Firth College, Sheffield.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *LEATHAM, EDWARD ALDAM. 46 Eaton-square, London, S.W.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡LEBOUR, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1861. ‡Lee, Henry. Sedgeley Park, Manchester.
1887. *Lee, Sir Joseph Cooksey. Park Gate, Altrincham.
1891. §Lee, Mark. 8 Llandaff-road, Cardiff.
1884. *Leech, Sir Bosdin T. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *LEES, CHARLES H., M.Sc. 6 Heald-road, Rusholme, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1883. *Leese, Miss H. K. 3 Lord-street West, Southport.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡LE FEUVRE, J. E. Southampton.
1872. ‡LEFEVRE, The Right Hon. G. SHAW, M.P., F.R.G.S. 18 Bryanston square, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. §Lehfeldt, Robert A. Firth College, Sheffield.
1868. ‡LEICESTER, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1890. §§Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. 11 The Avenue, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 28 Portland-place, London, W.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1890. *Lester, Joseph Henry. 51 Arcade-chambers, St. Mary's Gate, Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1894. §Leudesdorf, Charles. Pembroke College, Oxford.
1887. ‡*Leverkus, Otto. The Downs, Prestwich, Manchester.*

Year of
Election.

1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, London, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, London, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, D. Morgan, M.A. University College, Aberystwith.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T. The Mardy, Aberdare.
1860. ‡LIDDELL, The Very Rev. H. G., D.D. Ascot, Berkshire.
1887. ‡Liebermann, L. 54 Portland-street, Manchester.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1887. ‡Limpach, Dr. Crumpsall Vale Chemical Works, Manchester.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, London, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1883. ‡*Lipscomb, Mrs. Lancelot C. d'A. 95 Elgin-crescent, London, W.*
1883. ‡Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex. E.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *LIVERSIDGE, ARCHIBALD, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N.S.W. Care of Messrs. Kegan Paul, Trench, Trübner & Co., Charing Cross-road, W.C.
1864.§§Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, John Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt. 4 Halkyn-avenue, Sefton Park, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. City of London College, Moorgate-street, London, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, London, W.C.
1867. *Locke, John. 231 Clarence-road, Kentish Town, London, N.W.
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.
1863. ‡LOCKYER, J. NORMAN, C.B., F.R.S., F.R.A.S. Royal College of Science, South Kensington, London, S.W.

Year of Election.

1886. *LODGE, ALFRED, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.

1875. *LODGE, OLIVER J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 2 Grove-park, Liverpool.

1894. *Lodge, Oliver W. F. 2 Grove-park, Liverpool.

1889. ‡Logan, William. Langley Park, Durham.

1876. ‡Long, H. A. Charlotte-street, Glasgow.

1883. *Long, William. Thelwall Heys, near Warrington.

1883. ‡Long, Mrs. Thelwall Heys, near Warrington.

1883. ‡Long, Miss. Thelwall Heys, near Warrington.

1866. ‡Longdon, Frederick. Osmaston-road, Derby.

1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.

1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.

1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.

1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.

1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.

1883. *Longton, E. J., M.D. Lord-street, Southport.

1861. *Lord, Edward. Adamroyd, Todmorden.

1894. §Lord, Edwin C. E., Ph.D. 247 Washington-street, Brooklyn, New York, U.S.A.

1889. ‡Lord, Riley. 75 Pilgrim-street, Newcastle-upon-Tyne.

1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, W.

1887. *LOVE, A. E. H., F.R.S. St. John's College, Cambridge.

1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.

1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 11 Campden Hill-square, London, W.

1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.

1875. *Lovett, W. Jesse, F.I.C. Sydney House, 17 St. David's-road, St. Anne's-on-Sea.

1892. §Lovibond, J. W. Salisbury, Wiltshire.

1889. ‡Low, Charles W. 84 Westbourne-terrace, London, W.

1867. *Low, James F. Monifieth, by Dundee.

1885. §Lowdell, Sydney Poole. Baldwyn's Hill, East Grinstead, Sussex.

1891. §Lowdon, John. St. Hilda's, Barry, Cardiff.

1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.

1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.

1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.

1884. ‡*Lowe, F. J. Elm-court, Temple, London, E.C.*

1886. *Lowe, John Landor, M.Inst.C.E. Engineer's Office, Midland Railway, Derby.

1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.

1894. §Lowenthal, Miss Nellie. 60 New North-road, Huddersfield.

1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.

1853. *LUBBOCK, The Right Hon. Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. High Elms, Down, Kent.

1881. ‡Lubbock, John B. 14 Berkeley-street, London, W.

1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.

1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.

1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.

1889. ‡Luckley, George. The Grove, Jesmond, Newcastle-upon-Tyne.

1891. *Lucovich, Count A. The Rise, Llandaff.

1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.

1881. ‡Luden, C. M. 4 Bootham-terrace, York.

Year of Election.

1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Mining Engineering in Yorkshire College. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. Grove Cottage, Roundhay, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, London, S.W.

1852. ‡*McAdam, Robert.* 18 *College-square East, Belfast.*
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON., F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J., F.L.S. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, F.R.G.S. 79 Holland Park, London, W.
1884. ‡Macarthur, D. Winnipeg, Canada.
1834. MACAULAY, JAMES, A.M., M.D. 25 Carlton-vale, London, N.W.
1840. **MacBrayne, Robert.* 65 *West Regent-street, Glasgow.*
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. *McClean, Frank, M.A., F.S.S. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1892. *McCowan, John, M.A., D.Sc. University College, Dundee.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.

Year of Election.

1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.

1884. ‡Macdougall, Alan, M.Inst.C.E. 32 Adelaide-street East, Toronto, Canada.

1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.

1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.

1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.

1885. ‡Macfarlane, J. M, D.Sc., F.R.S.E., Professor of Biology in the University of Pennsylvania, Lansdowne, Delaware Co., Pennsylvania, U S.A.

1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.

1884. ‡*Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.*

1867. *M'Gavin, Robert. Ballumbie, Dundee.

1888. ‡MacGeorge, James. 67 Marloes-road, Kensington, London, W.

1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.

1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.

1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.

1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.

1884. ***MacGregor, James Gordon**, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.

1885. ‡M'Gregor-Robertson, J., M.A., M.B. 26 Buchanan-street, Hillhead, Glasgow.

1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.

1867. ***M'Intosh, W. C.**, M.D., LL.D., F.R.S., F.R S.E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.

1884. ‡McIntyre, John, M.D. Odiham, Hants.

1883. ‡Mack, Isaac A. Trinity-road, Bootle.

1884. ‡Mackay, Alexander Howard, B.A., B.Sc. The Academy, Pictou, Nova Scotia, Canada.

1885. §**Mackay, John Yule**, M.D. The University, Glasgow.

1873. ‡**McKendrick, John G.**, M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. The University, Glasgow.

1883. ‡McKendrick, Mrs. The University, Glasgow.

1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.

1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.

1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.

1883. ‡Mackeson, Henry. Hythe, Kent.

1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.

1867. ‡**Mackie, Samuel Joseph.** 17 Howley-place, London, W.

1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.

1887. ‡Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.

1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.

1889. ‡McKinley, Rev. D. 33 Milton-street, West Hartlepool.

1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.

1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.

1867. ‡*Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.*

1872. ***McLachlan, Robert**, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.

1892. §**Maclagan, Sir Douglas**, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.

1892. ‡Maclagan, Philip K. D. 14 Belgrave-place, Edinburgh.

1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.

Year of Election.

1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'LAREN, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1892. *Maclean, Magnus, M.A., F.R.S.E. The University, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLEOD, HERBERT, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. ‡*Macleod, Reginald. Woodhall, Midlothian.*
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMAHON, Lieut.-General C. A., F.G.S. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MACMAHON, Major P. A., R.A., F.R.S., Professor of Electricity in the Artillery College, Woolwich. 40 Shaftesbury-avenue, London, W.C.
1878. *M'Master, George, M.A., J.P. Rathmines, Ireland.
1862. ‡Macmillan, Alexander. 21 Portland-place, London, W.
1888. ‡*McMillan, Robert.* 20 *Aubrey-street, Liverpool.*
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. Cincinnati, Ohio, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, Archibald White. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1887. §McRae, Charles, M.A., F.L.S. Department of Science and Art, South Kensington, London, S.W.
*MACRORY, EDMUND, M.A. 19 Pembridge-square, London, W.
1883. ‡*McWhirter, William.* 170 *Kent-road, Glasgow.*
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, London, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart. Stirling, N.B.
1883. ‡Maitland, P. C. 136 Great Portland-street, London, W.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡MALLET, JOHN WILLIAM, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.
1887. ‡MANCHESTER, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.

Year of
Election.

1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1894. §Manning, Percy. Watford, Herts.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E. 3 Westminster-chambers, London, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1889. ‡Manville, E. 3 Prince's-mansions, Victoria-street, London, S.W.
1887. *March, Henry Colley, M.D., F.S.A. 2 West-street, Rochdale.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. §Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1894. §Markoff, Dr. Anatolius. 36 Cambridge-street, Hyde Park, London, W.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, JOHN EDWARD, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1887. ‡*Marsden, Joseph. Ardenlea, Heaton, near Bolton.*
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. 72 Wellington-street, Leeds.
1887. ‡Marsh, J. E., M.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. Druim Shellach, Liberton, Midlothian.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1858. ‡*Marshall, Reginald Dykes. Adel, near Leeds.*
1836. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston. Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡MARTIN, H. NEWELL, M.A., M.D., D.Sc., F.R.S., Professor of Biology in Johns Hopkins University, Baltimore, U.S.A.
1883. *MARTIN, JOHN BIDDULPH, M.A., F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 8 Windsor-crescent, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Lyon House, New Barnet, Herts.
1890. §Martindale, William. 19 Devonshire-street, Portland-place, London, W.

Year of
Election.

*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1893. *Mason, Thomas. 6 Pelham-road, Sherwood Rise, Nottingham.
1891. *Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square. Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1894. §Mathews, G. B. Bangor.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, London, W.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 21 Augustus-road, Edgbaston, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡MATTHEWS, JAMES. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-upon-Tyne.
1890. ‡*Maund, E. A. 294 Regent-street, London, W.*
1893. §Mavor, Professor James. University of Toronto, Canada.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Kenley, Surrey.
1894. §Maxim, Hiram S. Baldwin's Park, Bexley, Kent.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1887. ‡Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1884. ‡*Mecham, Arthur. 11 Newton-terrace, Glasgow.*
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, London, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *MELDOLA, RAPHAEL, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, London, W.C.
1867. ‡MELDRUM, CHARLES, C.M.G., LL.D., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.
1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1881. §Melrose, James. Clifton Croft, York.

Year of Election.

1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General, Marquis of Valdora, LL.D. Chambéry, Savoie.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §MERIVALE, JOHN HERMAN, M.A., Professor of Mining in the College of Science, Newcastle-upon-Tyne.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S., Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 15 Grange-road, West Hartlepool.
1894. *Miers, H. A., M.A. British Museum, Cromwell-road, London, S.W.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. §MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., F.R.S.E., Librarian R.G.S. 109 West End-lane, Hampstead, London, N.W.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1892. *Millard, William Joseph Kelson, M.D., F.R.G.S. Holmleigh, Rockleaze, Stoke Bishop, Bristol.
1882. ‡Miller, A. J. 15 East Park-terrace, Southampton.
1875. ‡Miller, George. Brentry, near Bristol.
1892. ‡Miller, Hugh, F.R.S.E., F.G.S. 3 Douglas-crescent, Edinburgh.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. §Mills, Mansfeldt H., M.Inst.C.E. Mansfield Woodhouse, Mansfield.
1834. Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. Inveresk.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S., Professor of Mining and Geology in the Imperial College of Engineering, Tokio, Japan. Ingleside, Birdhurst Rise, South Croydon, Surrey.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.
1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, London, N.W.
1888. ‡*Milsom, Charles.* 69 *Pulteney-street, Bath.*
1880. ‡Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.

Year of Election.

1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker, LL.D. Newcastle-upon-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡Mivart, St. George, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. Hurstcote, Chilworth, Surrey.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig, F.R.S., F.C.S. 20 Avenue-road, Regent's Park, London, N.W.
1891. *Mond, Robert Ludwig, B.A., F.R.S.E. 20 Avenue-road, Regent's Park, London, N.W.
1882. *Montagu, Sir Samuel, Bart., M.P. 12 Kensington Palace-gardens, London, W.
1891. ‡Montefiore, Arthur, F.G.S., F.R.G.S. Care of London and South-Western Bank, South Hampstead, London, N.W.
1892. ‡Montgomery, Very Rev. J. F., D.D. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1881. §Moore, Henry. Collingham, Maresfield-gardens, Fitzjohn's-avenue, London, N.W.
1894. §Moore, H. E. 41 Bedford-row, London, W.C.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1857. *Moore, Rev. William Prior. Carrickmore, Galway, Ireland.
1871. ‡More, Alexander G., F.L.S., M.R.I.A. 74 Leinster-road, Dublin.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡Morgan, Alfred. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, London, S.W.
1891.§§Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1885. ‡Morgan, John. 57 Thomson-street, Aberdeen.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1891. ‡Morgan, Sir Morgan. Cardiff.
1882. §Morgan, Thomas. Cross House, Southampton.
1878. ‡Morgan, William, Ph.D., F.C.S. Swansea.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1867. ‡Morison, William R. Dundee.

Year of
Election.

1893. §Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 47 Broadhurst-gardens, South Hampstead, London, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., F.R.S., M.P. 95 Elm Park-gardens, London, S.W.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn, R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Daniel, C.B., M.A., F.L.S. 11 Kew Gardens-road, Kew.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
1880. ‡*Morris, M. I. E. The Lodge, Penclawdd, near Swansea.*
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
1890. ‡Morrison, Sir George W. Leeds.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1886. ‡Morrison, John T. Scottish Marine Station, Granton, N.B.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 209 Edge-lane, Liverpool.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hook House, Hook, near Winchfield, Hampshire.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1891. ‡*Moss, Arthur J., M.B. Penarth, Glamorganshire.*
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. Conservative Club, London, S.W.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., B.A. Colet House, Talgarth-road, London, W.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866. §MOTT, FREDERICK T., F.R.G.S. Crescent House, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Roseland, Meadfoot, Torquay.
1878. *MOULTON, J. FLETCHER, M.A., Q.C., M.P., F.R.S. 57 Onslow-square, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.
1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Cheltenham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.

Year of Election.

1894. §Mugliston, Rev. J., M.A. Newick House, Cheltenham.
1876. *Muir, Sir John, Bart. 6 Park-gardens, Glasgow.
1874. ‡MUIR, M. M. PATTISON, M.A. Caius College, Cambridge.
1876. ‡Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, Glasgow.
1872. ‡Muirhead, Alexander. D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. Bridge of Weir, Renfrewshire.
1884. **Muirhead-Paterson, Miss Mary. Laurieville, Queen's Drive, Crosshill, Glasgow.*
1883. ‡MULHALL, MICHAEL G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. §MÜLLER, F. MAX, M.A., Professor of Comparative Philology in the University of Oxford. 7 Norham-gardens, Oxford.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1885. ‡MUNRO, J. E. CRAWFORD, LL.D. 14 Upper Cheyne-row, Chelsea, London, S.W.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1864. ‡MURCH, SIR JEROM. Cranwells, Bath.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James Barclay. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1884. §Murphy, Patrick. Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1891. ‡Murray, G. R. M., F.R.S.E., F.L.S. British Museum (Natural History), South Konsington, London, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, JOHN, F.R.S.E. 'Challenger' Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 9 Ellison-place, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan, F.R.G.S. 2 Savile-row, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891.§§Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L., B A. Swanbourne, Winslow, Buckinghamshire.

1886. §NAGEL, D. H., M.A., F.C.S. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 16 Red Lion-street, Clerkenwell, London, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡NARES, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. St. Bernard's, Maple-road, Surbiton.

Year of Election.

1887. ‡Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.

1887. §Neild, Charles. 19 Chapel Walks, Manchester.

1883. *Neild, Theodore, B.A. Dalton Hall, Manchester.

1887. ‡Neill, Joseph S. Claremont, Broughton Park, Manchester.

1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.

1855. ‡Neilson, Walter. 172 West George-street, Glasgow.

1876. ‡*Nelson, D. M. 11 Bothwell-street, Glasgow.*

1886. ‡*Nettlefold, Edward. 51 Carpenter-road, Edgbaston, Birmingham.*

1868. ‡Nevill, Rev. H. R. The Close, Norwich.

1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.

1889. ‡Neville, F. H. Sidney College, Cambridge.

1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.

1842. New, Herbert. Evesham, Worcestershire.

1889. *Newall, H. Frank. Madingley Rise, Cambridge.

1891. *Newell, W. H. A. 10 Plasturton-gardens, Cardiff.

1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.

1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.

1889.§§Newstead, A. H. L., B.A. Roseacre, Epping.

1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.

1892. ‡NEWTON, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, London, S.W.

1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.

1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.

1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.

1867. ‡Nicholl, Thomas. Dundee.

1875. ‡Nicholls, J. F. City Library, Bristol.

1866. ‡NICHOLSON, Sir CHARLES, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.

1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.

1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.

1884. ‡NICHOLSON, JOSEPH S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.

1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.

1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.

1881. ‡Nicholson, William R. Clifton, York.

1893.§§Nickolls, John B., F.C.S. The Laboratory, Guernsey.

1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.

1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. 15 Blacket-place, Edinburgh.

1878. ‡NIVEN, CHARLES, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.

1886. ‡*Niven, George. Erkingholme, Coolhurst-road, London, N.*

1877. ‡Niven, Professor James, M.A. King's College, Aberdeen.

1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.

1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.

1863. *NOBLE, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, and Jesmond Dene House, Newcastle-upon-Tyne.

1879. ‡Noble, T. S., F.G.S. Lendal, York.

1886. ‡Nock, J. B. Mayfield, Penns, near Birmingham.

Year of Election.

1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. ‡Norfolk, F. 16 Carlton-road, Southampton.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., F.R.S., F.L.S. Burnmoor Rectory, Fence Houses, Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. ‡North, William, B.A., F.C.S. 84 Micklegate, York.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1894. §NOTCUTT, S. A., LL.M., B.A., B.Sc. (LOCAL SECRETARY). 9 Museum-street, Ipswich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1887. ‡Nursey, Perry Fairfax. 2 Trafalgar-buildings, Northumberland-avenue, London, W.C.
1883. *Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1894. §Ogden, James. Kilner Deyne, Rochdale.
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.
1893.§§Ogilvie, Miss Maria M., D.Sc. Gordon's College, Aberdeen.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Syrian House, Sale, near Manchester.
1892. §Oldham, H. Yule. Lecturer in Geography in the University of Cambridge.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.
1893. §Oldham, R. D., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, London, E.C.
1892. ‡Oliphant, James. 50 Palmerston-place, Edinburgh.
1863. ‡OLIVER, DANIEL, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew.
1887. ‡Oliver, Professor F. W., D.Sc. 10 Kew Gardens-road, Kew, Surrey.

Year of Election.
1883. ‡Oliver, J. A. Westwood. The Liberal Club, Glasgow.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. §Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's-terrace, Grimsby.
1860. *OMMANNEY, Admiral Sir ERASMUS, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, London, W.
1880. *Ommanney, Rev. E. A. St. Michael's and All Angels, Portsea, Hants.
1887. ‡_O'Neill, Charles. Glen Allan, Manley-road, Alexandra Park, Manchester._
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. ‡Ord, Miss Sarah. 2 Pembroke-vale, Clifton, Bristol.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Major R. T., R.E. Gibraltar.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡_Osborn, George. 47 Kingscross-street, Halifax._
1887. §O'Shea, L. T., B.Sc. Firth College, Sheffield.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1869. *_Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E._
1884. ‡Osler, William, M.D., Professor of the Institutes of Medicine in McGill University, Montreal, Canada.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Sansome-street, San Francisco, U.S.A.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1888. *Owen, Thomas. 8 Alfred-street, Bath.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1894. §Paget, Octavius. 158 Fenchurch-street, London, E.C.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *PALGRAVE, R. H. INGLIS, F.R.S., F.S.S. Belton, Great Yarmouth.
1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. 8 Upper Mount-street, Dublin.
1866. §Palmer, William. Waverley House, Waverley-street, Nottingham.
1872. *_Palmer, W. R. 1 The Cloisters, Temple, E.C._

Year of Election.
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1890. ‡*Pankhurst, R. M., LL.D. 8 Russell-square, London, W.C.*
1883. §Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1884. ‡Panton, Professor J. Hoyes, M.A., F.G.S. Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1874. ‡*Parker, Henry R., LL.D. Methodist College, Belfast.*
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1865. *Parkes, Samuel Hickling, F.L.S. Ashfield-road, King's Heath, Birmingham.
1879. ‡Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881.§§Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D., Professor of Anatomy in University College, Liverpool.
1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 911 Sherbrooke-street, Montreal, Canada.
1883. ‡*Paton, Rev. William. The Ferns, Parkside, Nottingham.*
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. ‡*Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.*
1876.§§Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. ‡Pattison, Samuel Rowles, F.G.S. 11 Queen Victoria-street, London, E.C.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. ‡Paul, J. Balfour. 30 Heriot-row, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, London, W.
1887. ‡Paxman, James. Hill House, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Joseph F., M.D. 78 Wimpole-street, London, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Wellington-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.

Year of Election.

1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡PEACH, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *PEARCE, HORACE, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1888. §Pearce, Rev. R. J., D.C.L., Professor of Mathematics in the University of Durham. 7 South Bailey, Durham.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, London, N.W.
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1881. ‡Pearson, Richard. 57 Bootham, York.
1870. ‡*Pearson, Rev. Samuel, M.A. Highbury-quadrant, London, N.*
1883. *Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.
1863. §Pease, H. F., M.P. Brinkburn, Darlington.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡PEEK, CUTHBERT E., M.A., F.S.A. 25 Bryanston-square, London, W.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, Sir John, G.C.M.G., M.P. 18 Arlington-street, London, S.W.
1887. §PENDLEBURY WILLIAM H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.
1894. §Pengelly, Miss. Lamorna, Torquay.
1894. §Pengelly, Miss Hester. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 16 Ellison-place, Newcastle-upon-Tyne.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1894. §Perkin, A. G., F.R.S.E., F.C.S., F.I.C. 8 Montpelier-terrace, Woodhouse Cliff, Leeds.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.

Year of Election.
1884. ‡PERKIN, WILLIAM HENRY, jun., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, London, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, London, N.W.
1886. ‡Perrin, Mrs. 23 Holland Villas-road, Kensington, London, W.
1879. ‡*Perry, James. Roscommon.*
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 31 Brunswick-square, London, W.C.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 13 Fourth Avenue, Brighton.
1882. ‡Pfoundes, Charles. Spring Gardens, London, S.W.
1886. ‡Phelps, Colonel A. 23 Augustus-road, Edgbaston, Birmingham.
1884. ‡Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. ‡Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, London, S.W.
1886. ‡*Phelps, Mrs. Hamshall, Birmingham.*
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. 3 Tower-villas, George-lane, Woodford, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1889. ‡Philipson, John. 9 Victoria-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1894. §Phillips, Staff-Commander E. C. D., R.N., F.R.G.S. 14 Hargreaves-buildings, Chapel-street, Liverpool.
1887. ‡Phillips, H. Harcourt, F C.S. 183 Moss-lane East, Manchester.
1892. §Phillips, J. H. Poole, Dorset.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1894. §Pickard-Cambridge, Rev. O. Bloxworth Rectory, Wareham.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Lindow Cottage, Lancaster.
1885. *PICKERING, SPENCER U., M.A., F.R.S., F.C.S. 48 Bryanston-square, London, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason County, Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square, London, W.
1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. University College, Toronto, Canada.
1883. ‡*Pilling, R. C. The Robin's Nest, Blackburn.*

Year of Election.

Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡Pirz, Anthony. Long Island, New York, U.S.A.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, London, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡*Pitt, George Newton, M.A., M.D. 34 Ashburn-place, South Kensington, London, S.W.*
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. ‡Pitt, Sydney. 12 Brunswick-gardens, London, W.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1842. PLAYFAIR, The Right Hon. Lord, K.C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1893. §Plowright, Henry J., F.G.S. Brampton Foundries, Chesterfield.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1892. §Popplewell, W. C., B.Sc. Claremont-road, Irlams-o'-th'-Height, Manchester.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Brechin Lodge, Cambridge-road, Southport.
1886. ‡*Porter, Paxton. Birmingham and Midland Institute, Birmingham.*
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-upon-Tyne.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1883. §Potts, John. Thorn Tree House, Chester-road, Macclesfield.
1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Waunarlwydd House, near Swansea.
1894. *Powell, Richard Douglas, M.D. 62 Wimpole-street, London, W.

Year of Election.

1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, Mosley-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡POYNTING, J. H., D.Sc., F.R.S., Professor of Physics in the Mason College, Birmingham. 11 St. Augustine's-road, Birmingham.
1884. §§Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. Brazenose College, Oxford.
1891. ‡Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.
1869. *PREECE, WILLIAM HENRY, C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. Llewellyn. Telegraph Department, Midland Railway, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1894. §Prentice, Manning, F.C.S. Woodfield, Stowmarket.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley. 14 The Exchange, Bradford, Yorkshire.
1894. §Preston, Arthur E. Piccadilly, Abingdon, Berkshire.
1893. *Preston, Martin Inett. 9 St. James's-terrace, Nottingham.
1893. §§PRESTON, Professor THOMAS. Trinity College, Dublin.
*PRESTWICH, JOSEPH, M.A., D.C.L., F.R.S., F.G.S., F.C.S. Shoreham, near Sevenoaks.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., D.D., F.R.S., F.R.A.S., Master of Pembroke College, Oxford.
1882. ‡Price, John E., F.S.A. 27 Bedford-place, Russell-square, London, W.C.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1892. ‡*Prince, Professor Edward E. St. Mungo's College, Glasgow.*
1875. ‡*Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.*
1883. ‡*Prince, Thomas. Horsham-road, Dorking.*
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1889. *Pritchard, Eric Law, M.D., M.R.C.S. St. Giles, Norwich.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 26 Wimpole-street, London, W.
1888. ‡Probyn, Leslie C. Onslow-square, London, S.W.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Grey-street, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1885. ‡Profeit, Dr. Balmoral, N.B.
1863. ‡*Proud, Joseph. South Hetton, Newcastle-upon-Tyne.*
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.
1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. Alvington, Slade-road, Ilfracombe.
1872. *Pryor, M. Robert. Weston, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, London, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.

Year of Election.

1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §**PUMPHREY, WILLIAM.** Lyncombe, Bath.
1885. §Purdie, Thomas, B.Sc., Ph.D., Professor of Chemistry in the University of St. Andrews. 14 South-street, St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡**PURSER, FREDERICK,** M.A. Rathmines, Dublin.
1866. ‡**PURSER,** Professor **JOHN,** M.A., M.R.I.A. Queen's College Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883.§§Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883.§§Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. ‡**PYE-SMITH,** P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, London, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1893. §Quick, James. University College, Bristol.
1894. §Quick, Professor Walter J. University of Missouri, Columbia, U.S.A.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, London, S.W.
1887. ‡*Rabone, John. Penderell House, Hamstead-road, Birmingham.*
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡*Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.*
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston.
1888. ‡Radway, C. W. 9 Bath-street, Bath.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. 3 Kent-gardens, Ealing, London, W.
Rake, Joseph. Charlotte-street, Bristol.
1894. ***RAMBAUT, ARTHUR** A., M.A., D.Sc., F.R.A.S., M.R.I.A., Andrews' Professor of Astronomy in the University of Dublin, and Astronomer Royal for Ireland. Dunsink Observatory, Co. Dublin.
1885. ‡Ramsay, Major. Straloch, N.B.
1863. ‡**RAMSAY, ALEXANDER,** F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1867. **Ramsay, W. F., M.D. 100 Sinclair-road, West Kensington Park, London, W.*
1876. ***RAMSAY, WILLIAM,** Ph.D., F.R.S., F.C.S., Professor of Chemistry in University College, London, W.C.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, London, W.
1887. ‡Ramsbottom, John. Fernhill, Alderley Edge, Cheshire.
1835. *Rance, Henry. 6 Ormonde-terrace, Regent's Park, London, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.

Year of Election.
1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.
1893. §§Ransom, W. B., M.D. The Pavement, Nottingham.
1863. §§RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡RANSOME, ARTHUR, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.
Ransome, Thomas. Hest Bank, near Lancaster.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 11 Stone-buildings, Lincoln's Inn, London, W.C.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1864. ‡Rate, Rev. John, M.A. Fairfield, East Twickenham.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1892. §Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 91 Upper Tulse-hill, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., Bart., G.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1886. ‡Rawson, W. Stepney, M.A., F.C.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. Queen-street, Lancaster.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.M.Inst.C.E. Grove Lodge, Muswell Hill, London, N.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1888. ‡Rednall, Miss Edith E. Ashfield House, Neston, near Chester.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, London, E.C.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1891. ‡Reece, Lewis Thomas. Somerset House, Roath, Cardiff.
1861. ‡REED, Sir EDWARD J., K.C.B., M.P., F.R.S. 75 Harrington-gardens, London, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill.
1891. *Reed, Thomas A. Bute Docks, Cardiff.
1891. §Rees, I. Treharne, M Inst.C.E. The Elms, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, London, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.

Year of
Election.

1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.G.S. 28 Jermyn-street, London, S.W.
1892. §Reid, E. Waymouth, B.A., Professor of Physiology in University College, Dundee.
1889. ‡Reid, George, Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. ‡Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1892.§§Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1893. §Reinach, Baron Albert von. Frankfort.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1894. §Rendall, G. H., M.A., Principal of University College, Liverpool.
1891. §Rendell, Rev. J. R. Whinside, Whalley-road, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. Hooley Lodge, Redhill.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Manchester and Salford Bank, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., V.P.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 23 Lady Barn-road, Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1887. ‡Rhodes, George W. The Cottage, Victoria Park, Manchester.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. §Rhodes, John George. Warwick House, 46 St. George's-road, London, S.W.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D. University College, Bristol.
1863. ‡RICHARDSON, Sir BENJAMIN WARD, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 15 Burnaby-gardens, Chiswick, London, W.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Isthmian Club, 150 Piccadilly, London, W.
1880. §Richardson, Hugh. Sedbergh School, Sedbergh R.S.O., Yorkshire.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.
1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡Richardson, W. B. Elm Bank, York.

Year of Election.

1876. §Richardson, William Haden. City Glass Works, Glasgow.

1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.

1891. §Riches, T. Harry. 8 Park-grove, Cardiff.

1886. §Richmond, Robert. Leighton Buzzard.

1868. ‡RICKETTS, CHARLES, M.D., F.G.S. 19 Hamilton-square, Birkenhead.

1877. ‡*Ricketts, James, M.D. St. Helens, Lancashire.*

*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.

1883. *RIDEAL, SAMUEL, D.Sc., F.C.S. 28 Victoria-mansions, London, S.W.

1862. ‡*Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.*

1894. §RIDLEY, E. P. (LOCAL SECRETARY). 6 Paget-road, Ipswich.

1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.

1889. ‡Ridley, Thomas D. Coatham, Redcar.

1884. ‡Ridout, Thomas. Ottawa, Canada.

1881. *Rigg, Arthur. 7 Portsdown-road, Maida Vale, London, W.

1883. *RIGG, EDWARD, M.A. Royal Mint, London, E.

1883. ‡*Rigg, F. F., M.A. 32 Queen's-road, Southport.*

1892. §§Rintoul, D., M.A. Clifton College, Bristol.

1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.

*RIPON, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, London, S.W.

1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.

1867. ‡Ritchie, William. Emslea, Dundee.

1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.

1869. *Rivington, John. Babbicombe, near Torquay.

1888. ‡Robb, W. J. Firth College, Sheffield.

1869. *ROBBINS, JOHN, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.

1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.

1887. *Roberts, Evan. Thorncliffe, 5 York-road, Southport.

1859. ‡Roberts, George Christopher. Hull.

1870. *ROBERTS, ISAAC, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.

1894. *Roberts, Miss Janora. 5 York-road, Birkdale, Southport.

1891. ‡*Roberts, Rev. John Crossby, F.R.G.S. 41 Derby-road, East Park, Northampton.*

1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, London, E.C.

1879. ‡Roberts, Samuel. The Towers, Sheffield.

1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.

1883. ‡ROBERTS, Sir WILLIAM, M.D., F.R.S. 8 Manchester-square, London, W.

1868. *ROBERTS-AUSTEN, W. CHANDLER, C.B., F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. Royal Mint, London, E.

1883. ‡Robertson, Alexander. Montreal, Canada.

1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.

1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.

1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. Athenæum Club, London, S.W.

1883. ‡Robertson, George H. Plas Newydd, Llangollen.

1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.

1876. ‡*Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.*

1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.

1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, London, N.W.

Year of
Election.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1886. ‡*Robinson, Edward E.* 56 *Dovey-street, Liverpool.*
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1887. ‡Robinson, Henry. 7 Westminster-chambers, London, S.W.
1887. ‡*Robinson, James. Akroydon Villa, Halifax, Yorkshire.*
1861. ‡*Robinson, John, M.Inst.C.E. Atlas Works, Manchester.*
1883. ‡Robinson, John. Engineer's Office, Barry Dock, Cardiff.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. †Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891.§§Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, London, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1876. ‡*Robson, Hazleton R.* 14 *Royal-crescent West, Glasgow.*
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1894. *Rodger, J. W. 80 Anerley-park, London, S.E.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1866. ‡Roe, Sir Thomas, M.P. Grove-villas, Litchurch.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1884. *Rogers, Walter M. Lamowa, Falmouth.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1876. ‡ROLLIT, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1894. *Rooper, T. Godolphin. The Elms, High Harrogate.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Eadenbreck, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., M.P., F.R.S., F.C.S. 10 Bramham-gardens, London, S.W.
1883. *Rose, J. Holland, M.A. 25 Dalebury-road, Upper Tooting, London, S.W.
1892. ‡Rose, Hugh. Kilravock Lodge, Blackford-avenue, Edinburgh.
1894. §Rose, T. K. 9 Royal Mint, London, E.
1885. †Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡*Ross, David, LL.D.* 32 *Nelson-street, Dublin.*
1887. ‡Ross, Edward. Marple, Cheshire.
1880. †Ross, Captain G. E. A., F.R.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.

Year of Election.

1891. §Roth, H. Ling. 32 Prescott-street, Halifax, Yorks.

1893. §§Rothera, G. B. Sherwood Rise, Nottingham.

1865. *Rothera, George Bell, F.L.S. Orston House, Sherwood Rise, Nottingham.

1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.

1884. *Rouse, M. L. 343 Church-street, Toronto, Canada.

1861. ‡ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.

1861. ‡Rowan, David. Elliot-street, Glasgow.

1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.

1887. ‡Rowe, Rev. Alfred W., M.A., F.G.S. Felstead, Essex.

1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.

1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.

1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.

1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.

1881. *Rowntree, Joseph. 37 St. Mary's, York.

1881. *ROWNTREE, J. S. The Mount, York.

1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.

1883. ‡ROY, CHARLES S., M.D., F.R.S., Professor of Pathology in the University of Cambridge. Trinity College, Cambridge.

1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.

1888. ‡Roy, Parbati Churn, B.A. Calcutta, Bengal, India.

1875. *RÜCKER, A. W., M.A., F.R.S., Professor of Physics in the Royal College of Science, London. (GENERAL TREASURER.) 19 Gledhow-gardens, South Kensington, London, S.W.

1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonard's-on-Sea.

1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.

1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.

1884. ‡*Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.*

1887. §Ruscoe, John, F.G.S. Ferndale, Gee Cross, near Manchester.

1847. ‡RUSKIN, JOHN, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.

1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.

1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.

1884. ‡Russell, George. 13 Church-road, Upper Norwood, London, S.E.

1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.

1883. *Russell, J. W. 16 Bardwell-road, Oxford.

Russell, John. 39 Mountjoy-square, Dublin.

1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.

1876. ‡Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.

1886. ‡Russell, Thomas H. 3 Newhall-street, Birmingham.

1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Lecturer on Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.

1886. ‡Rust, Arthur. Eversleigh, Leicester.

1883. *Ruston, Joseph. Monk's Manor, Lincoln.

1891. §Rutherford, George. Garth House, Taff's Well, Cardiff.

1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.

1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.

Rutson, William. Newby Wiske, Northallerton, Yorkshire.

1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.

Year of
Election.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. 186 Aldersgate-street, London, E.C.
1885.§§Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *ST. ALBANS, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George. F.G.S. 225 Castle-road, Cardiff.
1893. SALISBURY, The Most Hon. the Marquis of, K.G., F.R.S. (PRESIDENT). 20 Arlington Street, London, S.W.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡Salmond, Robert G. Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1894. §SAMUELSON, Sir BERNHARD, Bart., M.P., F.R.S. 56 Prince's-gate, London, S.W.
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1884. ‡Sanders, Henry. 185 James-street, Montreal, Canada.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. §SANDERSON, J. S. BURDON, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
1893.§§Sanderson, Oundle. 9 The Ropewalk, Nottingham.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1892. §Sang, William D. 28 Whyte's Causeway, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Hill House, Lyndhurst, Hants.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. ‡Saunders, Rev. J. C. Cambridge.
1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, William. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A., F.S.A. St. Thomas' Parsonage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1887. §SAYCE, Rev. A. H., M.A., D.D. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.

Year of Election.

1892. ‡Shields, John, D.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1863. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, JAMES N., M.Inst.C.E., F.G.S. 47 Victoria-street, London, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, London, W.C.
1888.§§Shoppee, G. A., M.A., LL.D. 61 Doughty-street, London, W.C.
1875. ‡SHORE, THOMAS W., F.G.S. Hartley Institution, Southampton.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital.
1889. ‡Sibley, Walter K., B.A., M.B. 7 Upper Brook-street, London, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson, M.P. Erlesdene, Bowdon, Cheshire.
1885. *SIDGWICK, HENRY, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, London, W.
1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. Upper Queen-street, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Lawnhurst, Didsbury, near Manchester.
1847. ‡SIMON, Sir JOHN, K.C.B., D.C.L., F.R.S., F.R.C.S., Consulting Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1893.§§Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., 9 Barton-street, West Kensington, London, W.
1894. §Simpson, Thomas. Fennymbre, Ealing, London, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mohendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892.§§Sisley, Richard, M.D. 11 York-street, Portman-square, London, W.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.

Year of Election.

1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. 13 Hyde Park-gate, London, S.W.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.G.S. Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, Evan W., M.A., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Cavendish-crescent North, The Park, Nottingham.
1881. ‡*Smallshan, John.* 81 *Manchester-road, Southport.*
1885. §Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1858. ‡*Smeeton, G. H.* *Commercial-street, Leeds.*
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. §Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡SMITH, ADAM GILLIES, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Wabash College, Crawfordsville, Indiana, U.S.A.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, London, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.
1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡SMITH, DAVID, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, London, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1887. §SMITH, Rev. F. J., M.A., F.R.S. Trinity College, Oxford.
1892. ‡Smith, Rev. Frederick. 16 Grafton-street, Glasgow.
1885. ‡Smith, Rev. G. A., M.A. 21 Sardinia-terrace, Glasgow.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, London, E.

Year of Election.

1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1883. ‡Smith, M. Holroyd. Royal Insurance Buildings, Crossley-street, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡**Smith, Robert H.**, M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1894. §Smith, T. Walrond. 45 Selborne-road, Brighton.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, London, W.C.
1887. ‡Smith, Dr. Wilberforce. 14 Stratford-place, London, W.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡**Smithells, Arthur**, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1892. §Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. ***Smyth, Charles Piazzi**, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1874. ‡Smyth, Henry. Eastern Villa, Newcastle, Co. Down, Ireland.
1857. ***Smyth, John**, M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. ***Snape, H. Lloyd**, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.
1888. ‡Snell, Albion T. Brightside, Salusbury-road, Brondesbury, London, N.W.
1887. ‡Snell, Rev. Bernard J., M.A. 5 Park-place, Broughton, Manchester.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1879. ***Sollas, W. J.**, M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, and Dartry Park-road, Rathgar, Dublin.
1892. *Somervail, Alexander. Torquay.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. ***Sorby, H. Clifton**, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1892. ‡Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.

Year of
Election.

1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡*Southall, Norman. 44 Cannon-street West, London, E.C.*
1887. §Sowerbutts, Eli, F.R.G.S. 44 Brown-street, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley, Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1889. ‡*Spence, Faraday. 67 Grey-street, Hexham.*
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1894. §Spiers, A. H. Newton College, South Devon.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 26 St. Andrew-square, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, London, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 5 Munster-terrace, Fulham, London, S.W.
1888. *Stacy, J. Sargeant. 7 and 8 Paternoster-row, London, E.C.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.
1883. ‡Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
1894. §Stansfield, Alfred. Royal Mint, London, E.
1893.§§Staples, Sir Nathaniel. Lisson, Cookstown, Ireland.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1876. ‡Starling, John Henry, F.C.S. 3 Victoria-road, Old Charlton, Kent.
Staveley, T. K. Ripon, Yorkshire.
1894. §Stavert, Rev. W. J., M.A., F.C.S. Burnsall Rectory, Skipton-in-Craven, Yorkshire.
1873. *Stead, Charles. Red Barn, Freshfield, Liverpool.
1881. ‡Stead, W. H. Orchard-place, Blackwall, London, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, London, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. §STEBBING, Rev. THOMAS R. R., M.A. Ephraim Lodge, The Common, Tunbridge Wells.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.

Year of Election.

1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1870. **Stevens, Miss Anna Maria. 23 Elm Grove-terrace, London-road, Salisbury.*
1880. *Stevens, J. Edward, LL.B. Le Mayals, near Swansea.
1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1889. ‡*Stevenson, T. Shannon. Westoe, South Shields.*
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. *Stewart, A. H. St. Thomas's Hospital, London, S.E.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 12 Montgomerie-crescent, Kelvinside, Glasgow.
1887. ‡*Stewart, George N. Physiological Laboratory, Owens College, Manchester.*
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. §Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡Stone, E. D., F.C.S. 19 Lever-street, Piccadilly, Manchester.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1886. ‡Stone, J. B. The Grange, Erdington, Birmingham.
1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.
1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, London, E.C.
1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.
1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, London, N.W.
1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, W.
1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.
1878. *Stoney, G. Gerald. 90 Meldon-terrace, Newcastle-upon-Tyne.

Year of Election.

1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, London, N.
1876. §Stopes, Henry, F.G.S. 31 Torrington-square, London, W.C.
1883. ‡Stopes, Mrs. 31 Torrington-square, London, W.C.
1887. ‡Storer, Edwin. Woodlands, Crumpsall, Manchester.
1887. *Storey, H. L. Caton, near Lancaster.
1873. §Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1884. §Storrs, George H. Gorse Hall, Stalybridge.
1888. *Stothert, Percy K. Audley, Park-gardens, Bath.
1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.
1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1876. ‡Strain, John. 143 West Regent-street, Glasgow.
1863. ‡Straker, John. Wellington House, Durham.
1889. ‡Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.
1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.
1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.
1889. §Streatfeild, H. S. The Limes, Leigham Court-road, Streatham, S.W.
*Strickland, Charles. 21 Fitzwilliam-place, Dublin.
1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.
1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.
1887. *Stroud, Professor H., M.A., D.Sc. College of Science, Newcastle-upon-Tyne.
1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.
1876. *STRUTHERS, JOHN, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.
1878. ‡Strype, W. G. Wicklow.
1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.
1872. *Stuart, Rev. Edward A., M.A. St. Matthew, Bayswater, 5 Prince's-square, London, W.
1892. ‡Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.
1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893.§§Stubbs, Arthur G. Sherwood Rise, Nottingham.
1888. *Stubbs, Rev. Elias T., M.A. 4 Springfield-place, Bath.
1885. §Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1879. *Styring, Robert. 5 Leopold-street, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. 9 Park-grove, Wordsworth-road, Birmingham.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, London, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. §Sutherland, James B. 10 Windsor-street, Edinburgh.
1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.

Year of Election.

1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1876. ‡*Swan, David, jun. Braeside, Maryhill, Glasgow.*
1881. §SWAN, JOSEPH WILSON, M.A., F.R.S. Lauriston, Bromley, Kent.
*SWANSEA, The Right Hon. LORD, F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §SWINBURNE, JAMES. 4 Hatherley-road, Kew Gardens, London.
1870. *Swinburne, Sir John, Bart., M.P. Capheaton, Newcastle-upon-Tyne.
1885. ‡*Swindells, Miss. Springfield House, Ilkley, Yorkshire.*
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1890. §SWINHOE, Colonel C. Avenue House, Oxford.
1891.§§Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. The Municipal Technical School, Gravesend.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Common, London, S.W.
1890. ‡Sykes, Joseph. 113 Beeston-hill, Leeds.
1887. *Sykes, T. H. Cheadle, Cheshire.
SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford. New College, Oxford.
1893.§§Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. Queen's College, Belfast.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. Dragon House, Bilbrook, near Taunton.
1886. §Symons, W. H., F.I.C., F.R.M.S. 130 Fellowes-road, Hampstead, London, N.W.
1872. ‡*Synge, Major-General Millington, R.E., F.R.G.S. United Service Club, Pall Mall, London, S.W.*

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *TAIT, LAWSON, F.R.C.S. The Crescent, Birmingham.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.S.S. 37 Charlotte-street, Portland-place, London, W.
1894. §Takakusu, Jyun, B.A. 17 Worcester-terrace, Oxford.
1890. ‡Talbot, Rev. E. S. The Vicarage, Leeds.
1893.§§Talbot, Herbert, M.I.E.E. 19 Addison-villas, Addison-street, Nottingham.
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1891. ‡Tanner, Colonel H. C. B., F.R.G.S. Fiesole, Bathwick Hill, Bath.
1890. ‡TANNER, H. W. LLOYD, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.

Year of Election.

1892. *Tansley, Arthur G. 167 Adelaide-road, London, N.W.
1883. §Tapscott, R. L., F.G.S. 62 Croxteth-road, Liverpool.
1878. ‡TARPEY, HUGH. Dublin.
1861 *Tarratt, Henry W. St. Augustine, Southbourne, Christchurch, Hants.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1893. §§Tate, George, Ph.D., F.C.S. College of Chemistry, Duke-street, Liverpool.
1890. ‡Tate, Thomas, F.G.S. 5 Eldon-mount, Woodhouse-lane, Leeds.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt, F.C.S. 13 Queen's-terrace, St. John's Wood, London, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, London S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1887. ‡TAYLOR, Rev. Canon ISAAC, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. The Old Palace, Richmond, Surrey.
1873. ‡*Taylor, John Ellor, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.*
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1893. §Taylor, W. F. Boswell Court, Croydon, Surrey.
1894. *Taylor, W. W. 10 King-street, Oxford.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡TEALE, THOMAS PRIDGIN, M.A., F.R.S. 38 Cookridge-street, Leeds.
1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, London, S.W.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡TEMPLE, Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., M.P., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1894. §Terras, J. A., B.Sc. Royal Botanic Gardens, Edinburgh.
1882. §Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Sir Joseph. Hawthorn Villa, York.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, London, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., C.I.E., M.A., B.Sc., Ph.D., F.R.S., F.L.S. Royal Gardens, Kew.

Year of Election.

1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. §Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1883. ‡*Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.*
1884. ‡THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1892. ‡*Thomas, J. C., B.Sc. Queen Elizabeth's Grammar School, Carmarthen.*
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1891. ‡Thomas, John Tubb, L.R.C.P. Eastfields, Newport, Monmouthshire.
1880. *Thomas, Joseph William, F.C.S. Drumpellier, Brunswick-road, Gloucester.
1883. §Thomas, Thomas H. 45 The Walk, Cardiff.
1383. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886.§§Thomason, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.
1885. ‡Thompson, D'Arcy W., B.A., Professor of Physiology in University College, Dundee. University College, Dundee.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1859. ‡Thompson, George, jun. 5 Golden-square, Aberdeen.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1889. ‡*Thompson, Henry. 2 Eslington-terrace, Newcastle-upon-Tyne.*
1883. *Thompson, Henry G., M.D. 86 Lower Addiscombe-road, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. Woodstock, Waverley-road, Liverpool.
1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Principal and Professor of Physics in the City and Guilds of London Institute, Finsbury Technical Institute, E.C.

Year of Election.

1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1894. §Thomson, Arthur, M.D., Professor of Human Anatomy in the University of Oxford. Exeter College, Oxford.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1868. §THOMSON, JAMES, F.G.S. 6 Stewart-street, Shawlands, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1891. ‡Thomson, John. 70A Grosvenor-street, London, W.
1890.§§Thomson, J. Arthur, M.A., F.R.S.E., Lecturer on Zoology at the School of Medicine, Edinburgh. 30 Royal-circus, Edinburgh.
1883. ‡THOMSON, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. 6 Scrope Terrace, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S., Professor of Chemistry in King's College, London. 53 Prince's-square, London, W.
1886. ‡Thomson, Joseph. Thornhill, Dumfriesshire.
1863. ‡Thomson, Murray. 44 Victoria-road, Gipsy Hill, London, S.E.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1886. §Thornley, J. E. Lyndon, Bickenhill, near Birmingham.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Sir Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lypiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. 87 Selborne-street, Liverpool.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 24 Crouch Hall-road, Crouch End, London, N.
1871. ‡THORPE, T. E., Ph.D., F.R.S., F.R.S.E., F.C.S., Principal Chemist of the Government Laboratories, Somerset House, London, W.C.
1883. §Threlfall, Henry Singleton. 12 London-street, Southport.
1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S Tudor House, Richmond Green, Surrey.
1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.
1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London, S.W.
1873. ‡Tilghman, B. C. Philadelphia, U.S.A.
1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.
1883. ‡Tillyard, Mrs. Fordfield, Cambridge.
1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.
1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.
1891. §Todd, Richard Rees. Portuguese Consulate, Cardiff.
1889. §Toll, John M. Carlton House, Kirkby, near Liverpool.
1887. ‡*Tolmé, Mrs. Melrose House, Higher Broughton, Manchester.*
1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.
1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.
1887. ‡Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.

Year of Election.

1887. ‡Tonge, James. Woodbine House, West Houghton, Bolton.
1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1887. ‡Topham, F. 15 Great George-street, London, S.W.
1886. ‡Topley, Mrs. W. 13 Havelock-road, Croydon.
1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.
1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.
1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.
1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1877. ‡Tozer, Henry. Ashburton.
1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.
1883. ‡TRAILL, A., M.D., LL.D. Ballylough, Bushmills, Ireland.
1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.
1875. ‡*Trapnell, Caleb. Severnleigh, Stoke Bishop.*
1868. ‡TRAQUAIR, RAMSAY H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.
1891. ‡Trayes, Valentine. Maindell Hall, near Newport, Monmouthshire.
1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.
Trench, F. A. Newlands House, Clondalkin, Ireland.
1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡TRIMEN, HENRY, M.B., F.R.S., F.L.S. Peradeniya, Ceylon.
1871. ‡TRIMEN, ROLAND, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, D.D., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 22 Cottesmore-gardens, Victoria-road, Kensington, London, W.
1885. §TROTTER, COUTTS, F.G.S., F.R.G.S. 17 Charlotte-square, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton Frederick T., M.A.., DSc., Trinity College, Dublin.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1885. *Tubby, A. H. Guy's Hospital, London, S.E.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. ‡Tuke, W. C. 29 Princess-street, Manchester.

Year of Election.

1883. ‡TUPPER, The Hon. Sir CHARLES, Bart., G.C.M.G., C.B., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.

1892.§§Turnbull, Alexander R. Ormiston House, Hawick.

1855. ‡Turnbull, John. 37 West George-street, Glasgow.

1893. §Turner, Dawson, M.B. 37 George-square, Edinburgh.

1891. ‡Turner, Miss E. R. Ipswich.

1882. ‡*Turner, G. S. 9 Carlton-crescent, Southampton.*

1883. ‡*Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.*

1894. *TURNER, H. H., M.A., B.Sc., Sec. R.A.S., Professor of Astronomy in the University of Oxford. The Observatory, Oxford.

1888. ‡Turner, J. S., J.P. Granville, Lansdowne, Bath.

1880. *TURNER, THOMAS, A.R.S.M., F.C.S., F.I.C. County Offices, Stafford.

1863. *TURNER, Sir WILLIAM, M.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.

1893.§§TURNEY, Sir JOHN, J.P. Alexandra Park, Nottingham.

1890. *Turpin, G. S., M.A., D.Sc. 2 St. James's-terrace, Nottingham.

1885. ‡Turrell, Miss S. S. High School, Redland-grove, Bristol.

1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.

1884. *Tweddell, Ralph Hart. Meopham Court, Gravesend, Kent.

1886. *Twigg, G. H. 56 Claremont Road, Handsworth, Birmingham.

1888. §Tyack, Llewellyn Newton. University College, Bristol.

1882. §Tyer, Edward. Horneck, 16 Fitzjohn's-avenue, Hampstead, London, N.W.

1865. §TYLOR, EDWARD BURNETT, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.

1883. ‡Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.

1861. *Tysoe, John. Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.

1888. ‡Underhill, H. M. 7 High-street, Oxford.

1886. ‡Underhill, Thomas, M.D. West Bromwich.

1885. §Unwin, Howard. Newton-grove, Bedford Park, Chiswick, London.

1883. §Unwin, John. Eastcliffe Lodge, Southport.

1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.

1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, London, W.

1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.

1872. ‡Upward, Alfred. 150 Holland-road, London, W.

1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.

1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.

1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.

1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.

1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.

1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.

1884. ‡Van Horne, Sir W. C., K.C.M.G. Dorchester-street West, Montreal, Canada.

1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.

Year of Election.
1886. ‡VARDY, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. 5 Gayton-road, Hampstead, London, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, London, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, London, W.
1887. *VAUGHAN, His Eminence Cardinal. Archbishop's House, Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. †Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.R.S., F.C.S. 22 Norham-road, Oxford.
1873. *VERNEY, Sir EDMUND H., Bart., R.N., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Lady. Claydon House, Winslow, Bucks.
1883. ‡VERNON, H. H., M.D. York-road, Birkdale, Southport.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Major R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, London, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *VINES, SYDNEY HOWARD, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian Stephen. Llantrisant.

1880. *Wackrill. Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, George Henry. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Yorkshire College, Leeds.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.
1880. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡Walcot, John. 50 Northumberland-street, Edinburgh.
1884. ‡Waldstein, Charles, M.A., Ph.D. Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1891. †Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1894. §Walford, Edwin A., F.G.S. West Bar, Banbury.
1882. *Walkden, Samuel. 3 West End-terrace, Winchester.
1893. §Walker, Alfred O., F.L.S. Nant-y-Glyn, Colwyn Bay.
1890. §Walker, A. Tannett. Hunslet, Leeds.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1885. ‡Walker, Charles Clement, F.R.A.S. Lilleshall Old Hall, Newport, Shropshire.
1883.§§Walker, Mrs. Emma. 18 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
1891. §Walker, Frederick W. Hunslet, Leeds.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1894. §WALKER, G. T. Trinity College, Cambridge.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1894. *Walker, James, M.A. 30 Norham-gardens, Oxford.
1885. ‡WALKER, General J. T., C.B., R.E., LL.D., F.R.S., F.R.G.S. 13 Cromwell-road, London, S.W.

Year of Election.

1866. *WALKER, JOHN FRANCIS, M.A., F.C.S., F.G.S., F.L.S. 45 Bootham, York.

1855. ‡WALKER, JOHN JAMES, M.A., F.R.S. 12 Denning-road, Hampstead, London, N.W.

1867. *Walker, Peter G. 2 Airlie-place, Dundee.

1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.

1860. ‡Walker, S. D. 38 Hampden-street, Nottingham.

1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.

1888.§§Walker, Sydney F. 195 Severn-road, Cardiff.

1887. ‡Walker, T. A. 15 Great George-street, London, S.W.

1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.

Walker, William. 47 Northumberland-street, Edinburgh.

1881. *Walker, William. 18 Lendall, York.

1883. ‡Wall, Henry. 14 Park-road, Southport.

1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.

1892. ‡Wallace, Robert W. 14 Frederick-street, Edinburgh.

1887. *WALLER, AUGUSTUS, M.D., F.R.S. Weston Lodge, 16 Grove End-road, London, N.W.

1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.

1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.

1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.

1886. ‡Wallis, Whitworth, F.S.A. Westfield, Westfield-road, Edgbaston, Birmingham.

1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.

1894. *Walmisley, A. T., M.Inst.C.E. 9 Victoria-street, London, S.W.

1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.

1891. §Walmsley, Professor R. M., D.Sc. Heriot Watt College, Edinburgh.

1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.

1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.

1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.

1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.

1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.

1887. ‡Ward, A. W., M.A., Litt.D., Principal of Owens College, Manchester.

1874. §Ward, F. D., J.P., M.R.I.A. Wyncroft, Adelaide Park, Belfast.

1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.

1879. ‡WARD, H. MARSHALL, M.A., F.R.S., F.L.S., Professor of Botany in the Royal Indian Civil Engineering College, Cooper's Hill, Egham.

1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.

1874. §Ward, John, F.S.A. Lenoxvale, Belfast.

1887. §WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.

1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.

1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.

1884. *Ward, John William. Newstead, Halifax.

1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.

1887. ‡Ward, Thomas. Brookfield House, Northwich.

1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.

1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.

1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.

1884.§§Wardwell, George J. Rutland, Vermont, U.S.A.

1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.

1878. §WARINGTON, ROBERT, F.R.S., F.C.S. Harpenden, St. Albans, Herts.

Year of
Election.

1882. ‡Warner, F. I., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. 6 Windsor-terrace, Clifton, Bristol.
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, London, S.W.
1893.§§Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Lieut.-Colonel J. 40 Hamilton-terrace, London, N.W.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. Alton Cottage, Bottville-road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1892. §Watson, G. 9 Victoria-chambers, South Parade, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1887. ‡ *Watson, J. Beauchamp. Gilt Hall, Carlisle.*
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. 5 Loraine-terrace, Low Fell, Gateshead.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 23 Cross-street, Finsbury, London, E.C.
1892. §Watson, William, M.D. Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones, Cumberland.
1894. *Watson, W. 20 Rosetti-mansions, London, S.W.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1864. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.
1891. *Watts, E. Hannay, F.R.G.S. Springfield, Newport, Monmouthshire.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W., M.A., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and Corndon, Worcester-road, Sutton, Surrey.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡Webb, Sidney. 4 Park-village East, London, N.W.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, London, S.W.

Year of Election.

1891. §§Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.

1850. ‡Webster, John. Edgehill, Aberdeen.

1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.

1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, London, S.W.

1889. **Webster, William, F.C.S. 50 Lee Park, Lee, Kent.*

1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.

1889. ‡Weeks, John G. Bedlington.

1890. §Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.

1886. ‡Weiss, Henry. Westbourne-road, Birmingham.

1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.

1894. §Weld, Miss. Conal More, Norham Gardens, Oxford.

1876. *WELDON, W. F. R., M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, London, W.

1880. *Weldon, Mrs. 30A Wimpole-street, London, W.

1881. §Wellcome, Henry S. First Avenue Hotel, Holborn, London, W.C.

1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.

1881. §Wells, Rev. Edward, B.A. West Dean Rectory, Salisbury.

1894. §Wells, J. G. Selwood House, Shobnall-street, Burton-on-Trent.

1883. ‡Welsh, Miss. Girton College, Cambridge.

1887. *Welton, T. A. Rectory House-grove, Clapham, London, S.W.

1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.

1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.

Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.

1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.

1886. §Wertheimer, Julius, B.A., B.Sc., F.C.S., Professor of Chemistry in the Merchant Venturers' Technical College, Bristol.

1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.

1853. ‡West, Alfred. Holderness-road, Hull.

1853. ‡West, Leonard. Summergangs Cottage, Hull.

1853. ‡ *West, Stephen. Hessle Grange, near Hull.*

1882. *Westlake, Ernest, F.G.S. Vale of Health, Hampstead, N.W.

1882. ‡Westlake, Richard. Portswood, Southampton.

1875. *Weston, Sir Joseph D., M.P. Dorset House, Clifton Down, Bristol.

1882. ‡WETHERED, EDWARD, F.G.S. 4 St. Margaret's-terrace, Cheltenham.

1884. ‡Wharton, E. R., M.A. 4 Broad-street, Oxford.

1885. *WHARTON, Captain W. J. L., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.

1888. ‡Wheatcroft, William G. 6 Widcombe-terrace, Bath.

1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.

1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.

1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.

1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.

Year of
Election.

1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1888. §Whelen, John Leman. Bank House, 16 Old Broad-street, London, E.C.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *WHETHAM, W. C. D., M.A. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, London, S.W.
1874. ‡Whitaker, Henry, M.D. Fortwilliam Terrace, Belfast.
1883. *Whitaker, T. Savile Heath, Halifax.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and 33 East Park-terrace, Southampton.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, London, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, near Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent-street, Nottingham.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 8 Albemarle-street, London, W.
1883. *White, Mrs. 8 Albemarle-street, London, W.
1886. *White, William. The Ruskin Museum, Sheffield.
1861. **Whitehead, Peter Ormerod. 99 New John-street West, Birmingham.*
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1884. ‡*Whiteley, Joseph. Huddersfield.*
1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 239 Woodborough-road, Nottingham.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Canon C. T., M.A., F.R.A.S. Bedlington Vicarage, Northumberland.
1891. §Whitmell, Charles Thomas, M.A., B.Sc., F.G.S. 47 Park-place, Cardiff.
1857. *WHITTY, Rev. JOHN IRWINE, M.A., D.C.L., LL.D. 1 Rodbourne-villas, Crescent-road, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, London, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir Henry, Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1885. ‡*Wigglesworth, Alfred. Gordondale House, Aberdeen.*

Year of Election.

1883. ‡Wigglesworth, Mrs. Ingleside, West-street, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W. Plough-court, 37 Lombard-street, London, E.C.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1881. ‡WILBERFORCE, W. W. Fishergate, York.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *WILDE, HENRY, F.R.S. The Hurst, Alderley Edge, Manchester.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1892. §§Wilkinson, Rev. J. Frome. Kivington Rectory, Orston, Nottingham.
1886. *Wilkinson, J. H. Corporation-street, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. The Polygon, Ardwick, Manchester.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1872. ‡WILLETT, HENRY, F.G.S. Arnold House, Brighton.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, London, W.
1887. ‡Williams, Sir E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. Alban, M.A. Christ Church, Oxford.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. The Cedars, Llandaff-road, Cardiff.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katherine. Llandaff House, Pembroke-vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡WILLIAMS, MATTHEW W., F.C.S. 26 Elizabeth-street, Liverpool.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.
1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1883. ‡Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1888. ‡Williams, W. Cloud House, Stapleford, Nottinghamshire.
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
WILLIAMSON, WILLIAM C., LL.D., F.R.S., Emeritus Professor of Botany in Owens College, Manchester. 48 Elms-road, Clapham Common, London, S.W.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, London, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1880. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.

Year of Election.

1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 19 Little Queen-street, Westminster, S.W.
1874. ‡WILSON, Colonel Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 99 Albany-street, Regent's-park, London, N.W.
1875. ‡WILSON, GEORGE FERGUSSON, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Farnborough Lodge, R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1886. ‡Wilson, J. E. B. Woodslee, Wimbledon, Surrey.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1865. ‡WILSON, Ven. JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1894. §Wilson, Rev. R. J., M.A., Warden of Keble College, Oxford. Oxford.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona, Streete, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.
1877. ‡Windeatt, T. W. Dart View, Totnes.
1886.§§WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., Professor of Anatomy in Mason College, Birmingham.
1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1893. *Winter, G. K., M.Inst.C.E., F.R.A.S. Arkonam, Madras, India.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1894. §Witley, Arthur. 17 Acton-lane, Harlesden, London, N.W.
1888. ‡WODEHOUSE, E. R., M.P. 56 Chester-square, London, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, London, W.C.

Year of Election.
1883. *WOOD, JAMES, LL.D. Grove House, Scarisbrick-street, Southport.
1881.§§Wood, John, B.A. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1886. ‡*Wood, Rev. Joseph. Carpenter-road, Birmingham.*
1893.§§Wood, Joseph T. 29 Muster's-road, West Bridgeford, Nottinghamshire.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.C.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodcock, T., M.A. 150 Cromwell-road, London, S.W.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1888. *Woodiwiss, Mrs. Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*WOODS, EDWARD, M.Inst.C.E. 8 Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. 16 Adelaide-street, Leamington.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, London, S.W.
1887. *WOODWARD, ARTHUR SMITH, F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1869. *WOODWARD, C. J., B.Sc. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, London, S.W.
1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡WOODWARD, HORACE B., F.G.S. Geological Museum, Jermyn-street London, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S.A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. Victoria Bridge, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.

Year of Election.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1884. ‡Wragge, Edmund. 100 Wellesley-street, Toronto, Canada.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1857. ‡Wright, E. Perceval, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1831. Wright, T. G., M.D. 91 Northgate, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡Wrightson, Thomas, M.P., M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1887. ‡Wrigley, Rev. Dr., M.A., M.D., F.R.A.S. 15 Gauden-road, London, S.W.
1876. ‡Wünsch, Edward Alfred, F.G.S. Carharrack, Scorrier, Cornwall.
1892. ‡*Wyld, Norman. University Hall, Edinburgh.*
1883. §Wyllie, Andrew. 1 Leicester-street, Southport.
1885. ‡Wyness, James D., M.D. 349 Union-street, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡Wynne, Arthur Beevor, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.
1894. *Yarrow, A. F. Poplar, London, E.
1865. ‡*Yates, Edwin. Stonebury, Edgbaston, Birmingham.*
1883. §Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, London, S.E.
1886. *Young, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1894. *Young, George, Ph.D. Firth College, Sheffield.
1884. ‡Young, Sir Frederick, K.C.M.G. 5 Queensberry-place, London, S.W.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡Young, John, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.

Year of
Election.

1886. §Young, R. Fisher. New Barnet, Herts.
1883. *YOUNG, SYDNEY, D.Sc., F.R.S., F.C.S., Professor of Chemistry in University College, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, London, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Svante Arrhenius. The University, Stockholm.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 7, 6A, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1893. Professor Christian Bohr. 62 Bredgade, Copenhagen.
1880. Professor Ludwig Boltzmann. München.
1887. His Excellency R. Bonghi. Rome.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Boston, Massachusetts, United States.
1890. Professor Brentano. Maximilian-platz, München.
1893. Professor W. C. Brögger. Christiania.
1887. Professor J. W. Brühl. Heidelberg.
1884. Professor George J. Brush. Yale College, New Haven, United States.
1887. Professor G. Capellini. Royal University of Bologna.
1887. Professor J. B. Carnoy. Louvain.
1887. Dr. H. Caro. Mannheim.
1861. Dr. Carus. Leipzig.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Professor Dr. Ferdinand Cohn. The University, Breslau, Prussia.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
1880. Professor Cornu. L'École Polytechnique, Paris.
1870. J. M. Crafts, M.D. L'École des Mines, Paris.
1876. Professor Luigi Cremona. The University, Rome.
1889. W. H. Dall. United States Geological Survey, Washington, United States.
1862. Wilhelm Delffs, Professor of Chemistry in the University of Heidelberg.
1864. M. Des Cloizeaux. Rue Monsieur, 13, Paris.
1872. Professor G. Dewalque. Liége, Belgium.
1870. Dr. Anton Dohrn. Naples.
1890. Professor V. Dwelshauvers-Dery. Liége, Belgium.
1894. Professor W. Einthoven. Leiden.
1892. Professor F. Elfving. Helsingfors, Finland.
1876. Professor Alberto Eccher. Florence.
1892. Professor Léo Errera. The University, Brussels.
1874. Dr. W. Feddersen. Leipzig.
1886. Dr. Otto Finsch. Bremen.

Year of Election.
1887. Professor R. Fittig. Strasburg.
1872. W. de Fonvielle. 50 Rue des Abbesses, Paris.
1887. Professor Dr. Anton Fritsch. The University, Prague.
1892. Professor Dr. Gustav Fritsch. The University, Berlin.
1881. Professor C. M. Gariel, Secretary of the French Association for the Advancement of Science. 39 Rue Jouffroy, Paris.
1866. Dr. Gaudry. Paris.
1861. Dr. Geinitz, Professor of Mineralogy and Geology. Dresden.
1884. Professor J. Willard Gibbs. Yale College, New Haven, United States.
1884. Professor Wolcott Gibbs. Harvard University, Cambridge, Massachusetts, United States.
1889. G. K. Gilbert. United States Geological Survey, Washington, United States.
1892. Daniel C. Gilman. Johns Hopkins University, Baltimore, United States.
1870. William Gilpin. Denver, Colorado, United States.
1889. Professor Gustave Gilson. Louvain.
1889. A. Gobert. 222 Chaussée de Charleroi, Brussels.
1876. Dr. Benjamin A. Gould. Cambridge, Massachusetts, United States.
1884. General A. W. Greely. Washington, United States.
1892. Dr. C. E. Guillaume. Bureau International des Poids et Mesures, Pavillon de Breteuil, Sèvres.
1862. Dr. D. Bierens de Haan, Member of the Royal Academy of Sciences, Amsterdam. Leiden, Holland.
1876. Professor Ernst Haeckel. Jena.
1889. Horatio Hale. Clinton, Ontario, Canada.
1881. Dr. Edwin H. Hall. Baltimore, United States.
1872. Professor James Hall. Albany, State of New York.
1889. Dr. Max von Hantken. Budapesth.
1887. Fr. von Hefner-Alteneck. Berlin.
1893. Professor Paul Heger. The University, Brussels.
1893. Professor Richard Hertwig. Munich.
1887. Professor W. His. Leipzig.
1893. Professor Hildebrand. Stockholm.
1887. S. Dana Horton. New York.
1881. Professor A. A. W. Hubrecht, LL.D., C.M.Z.S. Utrecht.
1887. Dr. Oliver W. Huntington. Harvard University, Cambridge, Massachusetts, United States.
1884. Professor C. Loring Jackson. Harvard University, Cambridge, Massachusetts, United States.
1867. Dr. J. Janssen, LL.D. The Observatory, Meudon, Seine-et-Oise.
1876. Dr. W. J. Janssen. Villa Frisia, Aroza, Graubünden, Switzerland.
1881. W. Woolsey Johnson, Professor of Mathematics in the United States Naval Academy. Annapolis, United States.
1887. Professor C. Julin. Liége.
1876. Dr. Giuseppe Jung. 7 Via Principe Umberto, Milan.
1877. M. Akin Kàroly. 92 Rue Richelieu, Paris.
1862. Aug. Kekulé, Professor of Chemistry. Bonn.
1884. Professor Dairoku Kikuchi, M.A. Imperial University, Tokio, Japan.
1873. Dr. Felix Klein. The University, Leipzig.
1874. Professor Dr. Knoblauch. The University, Halle, Germany.
1856. Professor A. Kölliker. Wurzburg, Bavaria.
1887. Professor Dr. Arthur König. Physiological Institute, The University, Berlin.
1887. Professor Krause. 31 Brueckenallee, Berlin.
1877. Dr. Hugo Kronecker, Professor of Physiology. The University, Bern, Switzerland.

Year of Election.

1887. Lieutenant R. Kund. German African Society, Berlin.
1887. Professor A. Ladenburg. Breslau.
1887. Professor J. W. Langley. 847½ Fairmount-street, Cleveland, Ohio, United States.
1882. Dr. S. P. Langley, D.C.L., Secretary of the Smithsonian Institution. Washington, United States.
1887. Professor Count Solms Laubach. Strasburg.
1887. Dr. Leeds, Professor of Chemistry at the Stevens Institute, Hoboken, New Jersey, United States.
1872. M. Georges Lemoine. 76 Rue d'Assas, Paris.
1887. Professor A. Lieben. Vienna.
1883. Dr. F. Lindemann. 40 Georgenstrasse, Munich.
1877. Dr. M. Lindemann, Hon. Sec. of the Bremen Geographical Society. Bremen.
1887. Professor Dr. Georg Lunge. The University, Zurich.
1871. Professor Jacob Lüroth. The University, Freiburg, Germany.
1871. Dr. Lütken. Copenhagen.
1887. Dr. Henry C. McCook. Philadelphia, United States.
1867. Professor Mannheim. Rue de la Pompe, 11, Passy, Paris.
1881. Professor O. C. Marsh. Yale College, New Haven, United States.
1887. Dr. C. A. Martius. Berlin.
1890. Professor E. Mascart, Membre de l'Institut. 176 Rue de l'Université, Paris.
1887. Professor D. Mendeléeff, D.C.L. St. Petersburg.
1887. Professor N. Menschutkin. St. Petersburg.
1887. Professor Lothar Meyer. Tübingen.
1884. Albert A. Michelson. Cleveland, Ohio, United States.
1848. Professor J. Milne-Edwards. Paris.
1887. Dr. Charles Sedgwick Minot. Boston, Massachusetts, United States.
1893. Professor H. Moissan. Paris.
1877. Professor V. L. Moissenet. L'École des Mines, Paris.
1864. Dr. Arnold Moritz. The University, Dorpat, Russia.
1887. E. S. Morse. Peabody Academy of Science, Salem, Massachusetts, United States.
1889. Dr. F. Nansen. Christiania.
1864. Herr Neumayer. Deutsche Seewarte, Hamburg.
1884. Professor Simon Newcomb. Washington, United States.
1869. Professor H. A. Newton. Yale College, New Haven, United States.
1887. Professor Noelting. Mühlhausen, Elsass.
1890. Professor W. Ostwald. Leipzig.
1889. Professor A. S. Packard. Brown University, Providence, Rhode Island, United States.
1890. Maffeo Pantaleoni, Director of the Royal Superior School of Commerce. Bari, Italy.
1887. Dr. Pauli. Höchst-on-Main, Germany.
1890. Professor Otto Pettersson. Stockholm.
1870. Professor Felix Plateau. 152 Chaussée de Courtrai, Gand.
1884. Major J. W. Powell, Director of the Geological Survey of the United States. Washington, United States.
1887. Professor W. Preyer. The University, Berlin.
1886. Professor Putnam, Secretary of the American Association for the Advancement of Science. Harvard University, Cambridge, Massachusetts, United States.
1887. Professor G. Quincke. Heidelberg.
1868. L. Radlkofer, Professor of Botany in the University of Munich.
1886. Rev. A. Renard. Royal Museum, Brussels.
1873. Professor Baron von Richthofen. Kurfürstenstrasse, 117, Berlin.

Year of Election.
1887. Dr. C. V. Riley. Washington, United States.
1892. Professor Rosenthal, M.D. Erlangen, Bavaria.
1890. A. Lawrence Rotch. Boston, Massachusetts, United States.
1881. Professor Henry A. Rowland. Baltimore, United States.
1887. M. le Marquis de Saporta. Aix-en-Provence, Bouches du Rhône.
1883. Dr. Ernst Schröder. Karlsruhe, Baden.
1874. Dr. G. Schweinfurth. Cairo.
1846. Baron de Selys-Longchamps. Liége, Belgium.
1873. Dr. A. Shafarik. Prague.
1876. Professor R. D. Silva. L'École Centrale, Paris.
1892. Dr. Maurits Snellen, Chief Director of the Royal Meteorological Institute of the Netherlands. Utrecht.
1887. Ernest Solvay. Brussels.
1888. Dr. Alfred Springer. Cincinnati, Ohio, United States.
1866. Professor Steenstrup. Copenhagen.
1889. Professor G. Stefanescu. Bucharest.
1881. Dr. Cyparissos Stephanos. The University, Athens.
1881. Professor Dr. Rudolf Sturm. The University, Breslau.
1870. Professor Tchebichef, Membre de l'Académie de St. Pétersbourg.
1884. Professor Robert H. Thurston. Sibley College, Cornell University, Ithaca, New York, United States.
1864. Dr. Otto Torell, Professor of Geology in the University of Lund, Sweden.
1887. Dr. T. M. Treub. Java.
1887. Professor John Trowbridge. Harvard University, Cambridge, Massachusetts, United States.
Arminius Vámbéry, Professor of Oriental Languages in the University of Pesth, Hungary.
1890. Professor J. H. Van't Hoff. Amsterdam.
1889. Wladimir Vernadsky. Mineralogical Museum, Moscow.
1887. *Professor John Vilanova. Madrid.*
1886. M. Jules Vuylsteke. 80 Rue de Lille, Menin, Belgium.
1887. Professor H. F. Weber. Zurich.
1887. Professor L. Weber. Kiel.
1887. Professor August Weismann. Freiburg-im-Breisgau.
1887. Dr. H. C. White. Athens, Georgia, United States.
1881. Professor H. M. Whitney. Beloit College, Wisconsin, United States.
1887. Professor E. Wiedemann. Erlangen. [C/o T. A. Barth, Johannisgasse, Leipzig.]
1874. Professor G. Wiedemann. Leipzig.
1887. Professor R. Wiedersheim. Freiburg-im-Baden.
1887. Professor J. Wislicenus. Leipzig.
1887. Dr. Otto N. Witt. 33 Lindenallée, Westend-Charlottenburg, Berlin.
1876. Professor Adolph Wüllner. Aix-la-Chapelle.
1887. Professor C. A. Young. Princeton College, United States.
1887. Professor F. Zirkel. Leipzig.

LIST OF SOCIETIES AND PUBLIC INSTITUTIONS

TO WHICH A COPY OF THE REPORT IS PRESENTED.

GREAT BRITAIN AND IRELAND.

Admiralty, Library of the.
Anthropological Institute.
Arts, Society of.
Asiatic Society (Royal).
Astronomical Society (Royal).
Belfast, Queen's College.
Birmingham, Midland Institute.
Brighton Public Library.
Bristol Naturalists' Society.
Cambridge Philosophical Society.
Cardiff, University College of South Wales.
Chemical Society.
Civil Engineers, Institution of.
Cornwall, Royal Geological Society of.
Dublin, Geological Survey of Ireland.
——, Royal College of Surgeons in Ireland.
——, Royal Geological Society of Ireland.
——, Royal Irish Academy.
——, Royal Society of.
Dundee, University College.
East India Library.
Edinburgh, Royal Society of.
——, Royal Medical Society of.
——, Scottish Society of Arts.
Exeter, Albert Memorial Museum.
Geographical Society (Royal).
Geological Society.
Geology, Museum of Practical.
Glasgow Philosophical Society.
——, Institution of Engineers and Shipbuilders in Scotland.
Greenwich, Royal Observatory.
Kew Observatory.
Leeds, Mechanics' Institute.
Leeds, Philosophical and Literary Society of.
Linnean Society.
Liverpool, Free Public Library and Museum.
——, Royal Institution.
London Institution.
Manchester Literary and Philosophical Society.
——, Mechanics' Institute.
Mechanical Engineers, Institution of.
Meteorological Office.
Meteorological Society (Royal).
Newcastle-upon-Tyne, Literary and Philosophical Society.
——, Public Library.
Norwich, The Free Library.
Nottingham, The Free Library.
Oxford, Ashmolean Society.
——, Radcliffe Observatory.
Plymouth Institution.
Royal College of Physicians.
Royal College of Surgeons.
Royal Engineers' Institute, Chatham.
Royal Institution.
Royal Society.
Royal Statistical Society.
Salford, Royal Museum and Library.
Sheffield, Firth College.
Southampton, Hartley Institution.
Stonyhurst College Observatory.
Swansea, Royal Institution of South Wales
United Service Institution.
University College.
War Office, Library of the.
Yorkshire Philosophical Society.
Zoological Society.

EUROPE.

Berlin	Die Kaiserliche Akademie der Wissenschaften.
Bonn	University Library.
Brussels	Royal Academy of Sciences.
Charkow	University Library.
Coimbra	Meteorological Observatory.
Copenhagen	Royal Society of Sciences.
Dorpat, Russia	University Library.
Dresden	Royal Museum.
Frankfort	Natural History Society.
Geneva	Natural History Society.
Göttingen	University Library.
Grätz	Naturwissenschaftlicher Verein.
Halle	Leopoldinisch-Carolinische Akademie.
Harlem	Société Hollandaise des Sciences.
Heidelberg	University Library.
Helsingfors	University Library.
Kasan, Russia	University Library.
Kiel	Royal Observatory.
Kiev	University Library.
Lausanne	The University.
Leyden	University Library.
Liége	University Library.
Lisbon	Academia Real des Sciences.
Milan	The Institute.
Modena	Royal Academy.
Moscow	Society of Naturalists.
——	University Library.
Munich	University Library.
Naples	Royal Academy of Sciences.
Nicolaieff	University Library.
Paris	Association Française pour l'Avancement des Sciences.
——	Geographical Society.
——	Geological Society.
——	Royal Academy of Sciences.
——	School of Mines.
Pultova	Imperial Observatory.
Rome	Accademia dei Lincei.
——	Collegio Romano.
——	Italian Geographical Society.
——	Italian Society of Sciences.
St. Petersburg	University Library.
——	Imperial Observatory.
Stockholm	Royal Academy.
Turin	Royal Academy of Sciences.
Utrecht	University Library.
Vienna	The Imperial Library.
——	Central Anstalt für Meteorologie und Erdmagnetismus.
Zurich	General Swiss Society.

ASIA.

Agra	The College.
Bombay	Elphinstone Institution.
——	Grant Medical College.
Calcutta	Asiatic Society.
Calcutta	Presidency College.
——	Hooghly College.
——	Medical College.
Ceylon	The Museum, Colombo.
Madras	The Observatory.
——	University Library.

AFRICA.

Cape of Good Hope	The Royal Observatory.